Olympic Coast Marine Research

Proceedings of a Workshop Forks, Washington January 24-26, 1996

edited by Richard Strickland

June 1996

Olympic Coast National Marine Sanctuary
138 West First St.
Port Angeles, WA 98362
360/457-NOAA

Occasional Paper OCNMS 96-01

Olympic Coast Marine Research

Proceedings of a Workshop
held at the
Olympic Natural Resources Center
Forks, Washington
January 24-26, 1996

Editor: Richard Strickland
School of Oceanography
University of Washington
Seattle, WA 98195

Sponsored by
Olympic Coast National Marine Sanctuary
138 W. First Street
Port Angeles, WA 98362

Todd Jacobs, Sanctuary Manager
Ed Bowlby, Research Coordinator

June 1996

Contents

Introduction

Because the Olympic coastal waters represent a unique and rich environment and have special national significance, the U.S. Congress directed the Natioanl Oceanic and Atmospheric Administration (NOAA) to create the Olympic Coast National Marine Sanctuary (OCNMS or Sanctuary). It was formally dedicated in July, 1994. The goals of the Sanctuary are to protect marine resources and ecological diversity through public education and research and to encourage compatible uses. Its protected status complements the area's other designations, which include a National Wildlife Refuge, National Park, Biosphere Reserve, and World Heritage Site. The Sanctuary encompasses an area of approximately 3,300 square miles (8.575 square kilometers; Figure 1).

The Sanctuary was created with a research mandate (Appendix 1), and as part of research planning, the Sanctuary manager and Research Coordinator chose to convene a group of experts and interested parties who could help identify research needs and recommend how research efforts could be prioritized. To plan for this event, a Workshop Steering Committee (Appendix 2) was assembled by Ed Bowlby, the Research Coordinator. Selected research scientists, resource managers and users, and Native tribal members were invited to the workshop held on January 24-26, 1996, at the Olympic Natural Resources Center (ONRC) in Forks, Washington (see list of participants in Appendix 3).

The primary goals of the Olympic Coast Marine Research Workshop were:

- To enhance coordination of research across disciplines;
- To support development of long-term monitoring programs;
- To provide a starting point for future discussions regarding research needs of managers in addressing marine resource issues of the outer coast of the Olympic Peninsula.

During the course of this workshop, researchers were asked to identify key problems that drive the need for research within a number of topic areas. The workshop

also provided an opportunity for continued development of networks and contacts between researchers from diverse disciplines.

Table 1. Workshop Program

Date	Format	Time	Activity	Principal
Wednesday, January 24	Plenary Session	8:00 PM	Traditional knowledge & story telling	Tribal Elders
		10:00 PM	Day 1 Conclusion	
Thursday, January 25	Plenary Session	8:30 AM	Introduction	Ed Bowlby, OCNMS
		8:40 AM	Overview of Aberdeen Workshop	Miranda Wecker, ONRC
		9:30 AM	Discipline Sessions	Discipline Speakers
		12:00 PM	Lunch Break	
	Focus Groups	1:00 PM	Focus Group Discussions	Facilitators
		5:00 PM	Poster Session	
		6:00 PM	Day 2 Conclusion	
Friday, January 26	Plenary Session	8:00 AM	Interim Focus Group Summaries	Facilitators
	Focus Groups	9:00 AM	Focus Group Discussions (continued)	Facilitators
	Plenary Session	11:00 AM	Final Focus Group Summaries	Facilitators
		1:00 PM	Workshop Conclusion	

Program

The workshop program is presented in Table 1. The workshop began in the evening with a welcoming ceremony by tribal elders and members of the Makah, Quileute, and Hoh tribes, which share a coastal heritage and long history of sustainable use of marine resources. The tribal members shared traditional stories and music, and offered some personal experiences from and opinions about the future of the Olympic coast. The following tribal members participated:

Makah Tribe	Quileute Tribe	Hoh Tribe
Nytom John Goodwin	Chris Morganroth	Helen Lee
Crystal Hall		Alvin Penn
Edith Hottowe		Viola Riebe
Jeff Hottowe		Mary Williams
John Hottowe		
Steve Pendleton		
Quentin Vitalis		

The next morning, the workshop opened with all participants in plenary session. After brief introductory remarks by Ed Bowlby, OCNMS, the first speaker was Miranda Wecker, Marine Resource Manager for the Olympic Natural Resource Center (ONRC), where the workshop took place, was the first speaker. ONRC is a division of the University of Washington, and operates with state funding to facilitate research on how forest and marine resources may be used sustainably to support the economy of the Olympic Peninsula. Ms. Wecker outlined ONRC's mission and reported on the results of an earlier workshop held by ONRC in 1993 at Grays Harbor College in Aberdeen, Washington. Her remarks are presented in full in Appendix 4.

The discussions at the earlier workshop were shaped by ONRC's mandate to "meet the pressing need for objective and credible information to define better ways to manage uses of the forests and the sea." ONRC also was created to "help citizens of the state define policies that, at once, allow commodity production and protect key ecological values. . ." and to "explore the interrelationships and inter-connections between marine and terrestrial systems." ONRC's geographic scope includes the southern Washington coast, where there is much more commercial use of the marine environment than in the Sanctuary, so the Grays Harbor workshop featured broad discussions of the relationships of Olympic Coast resources to the local economy.

Following Ms. Wecker's presentation, a series of experts from the various research disciplines summarized existing knowledge and research concerning Sanctuary waters and resources (Table 1). The purpose of this plenary session was to summarize past progress and present status of the respective disciplines, so that all workshop participants would be familiar with developments outside of their immediate specialties. The scope of these talks included baseline studies, research, and monitoring—the three research elements identified in the research mandate (Appendix 1)—as well as gaps in the data record. These talks are presented in the next section of this report.

After the plenary session, the workshop participants separated into a series of concurrent focus groups, which discussed research status and needs within the discipline areas (Table 1). Participants were free to attend any and all sessions as they saw fit. Each group was led by one or more facilitators, who helped to guide the discussions and took notes. The facilitators presented interim results of each focus group discussion for the reassembled participants in plenary session at the beginning of the second day, and summarized their final results at the end of the workshop.

Each focus group was asked to address the following specific questions:

- What research activities have been or are being conducted, and what are their principal findings?
- What are the current and future uses of and demands/stresses on the marine environment?
- What are management concerns/issues compiled from previous conferences?
- What research is necessary, both basic and applied?
- What opportunities exist for collaborative efforts and standardizing protocols to increase research coordination and efficiency?

The results of the focus group discussions are summarized in narrative and tabular format later in this report. The discussions of one focus group (Prehistoric and Historic Uses and Archaeology) included a significant segment of information that would have been appropriate as a disciplinary talk during the plenary session. This material is included in Appendix 5.

On the evening of January 25, a poster session was held at the ONRC to present the recent research activities of some participants. Abstracts of these posters are included as Appendix 6 of this report.

Uses of the Workshop Results

The results of this workshop will be used by the Sanctuary management to help define broad objectives for research in the Sanctuary, and to select specific research projects and procedures to solicit and support, according to the Sanctuary's research mandate (Appendix 1). It will also identify areas where Sanctuary research activities can

be partnered with those of existing agencies, institutions, and tribal groups for more coordinated and cost-effective programs.

Acknowledgements

We gratefully acknowledge the assistance of the members of the Workshop Steering Committee at planning the workshop and evaluating its results. We thank the staff of the Olympic Natural Resources Center, especially June Powers and Miranda Wecker, for hosting the workshop, and to Paul Ringgold, former Acting Director of ONRC, who was indispensable in the startup planning stages. We also thank the members of the coastal tribes, mentioned above, who shared their heritage and experiences and offered good wishes for the workshop.

Discipline Sessions

Nearshore Ecology of the Olympic Coast

Robert Paine, University of Washington Department of Zoology

I am here to make a case for “Ivory Tower” ecological research on marine benthic and planktonic algae and invertebrates, not just the so-called “charismatic megafauna.” These more obscure organisms are really the powerhouse for much nearshore productivity. They are aesthetically pleasing; these organisms and this environment provide a superb vehicle for ecological manipulations. Experiments are really much more powerful tools than simple observation in ecology, and much of our ecological knowledge on how communities are organized has come from experiments over the last two or three decades.

My work at Makah Bay began in 1963 and later moved to Tatoosh Island with the permission of the Coast Guard and, after 1970, the Makah Tribal Council. I remain continuingly grateful to the Makah Tribe for the opportunity to do this work. It has produced one of the few long-term, benthic ecological time-series at the same site. Its applicability to other geographic locations is debatable, but its long-term value is unquestioned. I am tempted to argue that modern marine community ecology was born on Makah tribal lands: research there has produced a number of "citation classics" (Paine, Dayton at least), three Mercer Awards—recognition from the Ecological Society of America for outstanding research published by graduate students (Dayton, Sebens, Wootton), and numerous other recognitions. There are probably 40 to 60 publications in the primary literature detailing these studies; they provide an exceptional database extending from 1963 to the present.

I begin by asking, given the concept of a Sanctuary that is permeable to people, what constitutes essential research information. From an ecological perspective, one viewpoint predominates. We know that assemblages vary naturally in space and time. Anthropogenic influences tend to complicate the patterns. The fundamental question is this: how does one measure departure from this baseline, how can added "stress" be

recognized against the background of a noisy (meaning variable) system? I propose no answers, although I have opinions. Below I identify some of the databases available to address this problem of natural variation. Anthropogenic factors such as oil spills, excessive fishing, impacts of introduced or naturally invading species, or simply too many well-intentioned tourist visitors must be assessed against this varying background.

Natural Disturbance

This Washington State outer coast is characterized by continual severe disturbance; there is essentially no equilibrium state. There are strong direct physical and biological effects of disturbance, and there also can be more subtle indirect effects that can be difficult to observe. The most obvious disturbances are caused by wave action, which tears organisms off the rocks, thereby creating bare patches for recolonization. For example, it takes a mussel bed at least seven years to return to its original state.

These disturbances continuously generate diversity in the system. The percentage of disturbed area varies interannually from site to site, ranging from a low of zero percent to a high of 73 percent. At Tatoosh, the average disruption at 26 independent mussel beds ranges from a low of less than two percent to a high of 23 percent. There is no single cause. The cold water winter of 1975-76, the El Niño winter of 1983-84, and the severe freeze of February, 1989, all generated high levels of mussel mortality.

Another example is provided by the sea palm, *Postelsia*, a species widely recognized as an indicator of heavy wave action. Its percent cover undergoes tremendous interannual variations. Because its reproductive propagules (spores) disperse only a short distance from the parent plant, truly severe disturbances can cause it to go locally extinct (which explains why it is now protected in California, where it was exploited as a "sea vegetable"). Studies initiated in 1978 suggest that natural recolonization of denuded sites is less than six percent per year, and that the eventual persistence at such sites is less than two percent. Other common organisms in this habitat, such as barnacles, mussels, and sea urchins, are capable of much broader dispersal. However, perhaps 50 percent of the species present are poor dispersers, like *Postelsia,* and hence are subject to local extinction.

Ecological Interactions

One major accomplishment of experimental ecology has been to identify both that interspecific interactions are important and that indirect effects may even be more so.

The concept of "keystone species" was born at Makah Bay (Paine). Novel ways to quantify and explore the consequences of indirect effects have been developed from research at Tatoosh Island (Wootton). Below I provide a sampler of the sorts of data that exist.

- Sea urchins, probably the major invertebrate grazer in the system, have been experimentally removed from tide pools at both Makah Bay and Tatoosh. In the absence of urchins, the pools become completely dominated by fast growing, and highly productive, fleshy algae within a year.

- Areas dominated by coralline algae have been scraped clean and their recovery followed. When antifouling paint is used to exclude grazers, the scraped area becomes dominated by fleshy algae, whereas the controls revert to coralline algae. This is an example of a powerful indirect effect, because these grazers don't eat corallines, yet the recovery of the corallines depends on the presence of the grazers.

- Data on the effects of the presence of a peregrine falcon, which preyed on crows in addition to other species, also illustrates complex interactions. This predation on crows relieved predation pressure on the eggs of black oystercatchers, common murres, and pelagic cormorants. One unique data set shows that the local productivity of oystercatchers doubled as a result.

- Sea otters are well documented to be strong interactors in nearshore marine communities. They have been reestablished successfully in the Sanctuary and have, within the last few years, expanded their range to the north, past Tatoosh, and subsequently to the east. They already appear to have influenced urchin populations at Tatoosh; it will be essential that the Sanctuary management document their direct influence on the invertebrate assemblage and the related indirect impacts on benthic algae.

Future Research

I want to identify several guiding principles that I believe apply to future research in the Sanctuary. They are strongly influenced by the time I spent in the summer of 1994 in Prince William Sound as a guest of NOAA. Their monitoring of the aftermath of the *Exxon Valdez* spill provides an example against which to compare future monitoring plans. I have given some thought to how useful our long-term studies at Tatoosh would be if a similar spill happened there. Accurate physiological and ecological indicators of change are preferable to emotional grounds as the basis for management actions. We need to look at long-lived plant and animal species that have the equivalent of annual growth rings in trees. There are lots of candidate species, but few have been investigated. Perhaps the two most general lessons are:

- Long-term monitoring is important, but it is a waste of time and money monitor everything. Not all species are equally valuable or useful for scientific inquiry; intelligent choices must be made about which species to monitor.

- By monitoring fewer species, the spatial extent can be extended and site-specific replication increased. Such actions will increase the statistical power of analyses and therefore the robustness of the conclusions drawn.

For long-term prospects, it will be essential to balance tourist and exploitation pressures against the welfare of the natural shore assemblage. For that, adequate baseline data coupled with an understanding of species interactions are necessary. Oil spillage and the resultant wildlife mortality are another inevitable influence. To assess these and other more global effects, support of basic ecological endeavors must be considered; without them, management decisions will be based on preconceived views or politically expedient action. Neither will serve the Sanctuary well.

Seabirds of the Olympic Coast

Julia Parrish, University of Washington Department of Zoology

In making an inverntory of seabird populations, we can count either birds on a colony, birds at sea, or both. The most complete reference document for the Sanctuary waters is the Catalog of Washington Seabird Colonies by Steve Speich and Terry Wahl (1989), indicating that breeding bird populations are numerically dominated by alcids and storm-petrels. By contrast, data on seabirds at sea indicate that Sanctuary waters are dominated by shearwaters, gulls, and alcids.

Regional populations of several alcids—including marbled murrelets, tufted puffins, and common murres—are low or in decline. Marbled murrelets and murres are receiving some scientific attention, but the decline in puffins is virtually unnoticed. Murre numbers appear to be negatively correlated with sea surface temperature. Indirect effects of eagles, facilitating egg predators, also contribute to depressed murre demographics.

Human activities, both inside and outside the Sanctuary, can affect seabird populations breeding within the Sanctuary, because of migration and post-breeding dispersal of the birds. Seabirds suffer mortality from oil spills and entanglement in gill nets, and can be disturbed while on the breeding colonies by air and boat traffic. Although we attempt to quantify mortality by means of carcass counts after known events, such as the *Tenyo Maru* oil spill, we know little about the background mortality rate.

We are limited in our ability to study the seabirds of the Sanctuary by time, funding, and logistical constraints. Thus, we can not afford to be idealistic and must be pragmatic in designing long-term monitoring and innovative research programs.

Marine Mammals of the Olympic Coast

Pat Gearin, NMFS, National Marine Mammal Laboratory

Marine mammal research along the Washington coast has a lengthy chronology. The earliest information comes from native histories and oral accounts of early anthropologists. The Makah people were whalers and hunters. The earliest European explorers were whalers and fur traders seeking otters and seals. James G. Swan wrote accounts of the native mammals and the sealing and whaling activities during his stay on the coast between 1850 and 1860. Later descriptions were provided by C. Hart Merriam around the turn of the century; Victor Scheffer and Karl Kenyon, who conducted extensive baseline surveys between about 1930 and 1950; and Steve Jeffries, who began aerial surveys of coastal mammals. This work provides historical background for our current studies of marine mammal abundance and distribution.

There are about 29 marine mammal species in the Sanctuary. Pinnipeds congregate around low rocky reefs. The Ozette and Cape Alava area is a focus of activity, with about 1000 harbor seals, 400–500 Steller sea lions, 50–100 sea otters, a group of summer-resident gray whales, and an undetermined number of harbor porpoise (the most common small cetacean inshore) and orca whales. Tatoosh Island is another popular haulout area for seals and sea lions.

One of the few real experiments conducted with marine mammals was the reintroduction of sea otters, which had been extirpated decades before, to the Washington coast in 1969–1970. This reintroduction was very successful, and the population has been expanding northward. Last summer a group of more than 100 was seen in the outer Strait of Juan de Fuca.

In the Sanctuary there is a total of more than 1000 Steller sea lions, an endangered species whose numbers are seriously depleted in Alaska. Branding studies show that Stellers migrate here from the north and south during the non-breeding season. The Sanctuary also hosts a few elephant seals, which are common but rarely seen migrants through the area. Sightings have increased over the last decade.

Northern fur seals are probably the most abundant but least understood marine mammal in the Sanctuary. About 80,000 to 90,000 animals migrate through the

Sanctuary along about the 100 fathom isobath during March and April.

Most gray whales migrate through the Sanctuary on their route between summer feeding grounds in the Beaufort Sea and winter breeding grounds in Baja California. A few individuals remain in the Sanctuary during summer, fall, and winter rather than proceeding to Alaska. These whales are now being cataloged by John Calambokidis using their coloration patterns, which reveals that some individuals have returned for as long as ten years.

Orca whales Y1 and Y2, known as seal predators from inland waters, were observed as transients in the areas off Ozette with the most abundant harbor seal populations during summer in 1994 and 1995.

Offshore mammal populations were surveyed extensively in 1989 and 1990 in studies funded by the Minerals Management Service. Greg Green, who is at this meeting, participated in the studies. Humpback whales (also being photographically identified by John Calambokidis) have key offshore feeding areas. Pacific whitesided dolphins are also common offshore.

A number of marine mammal issues are looming for the future:

- The range expansion of sea otters into the Strait of Juan de Fuca poses conflicts with oil vessel traffic and with the native sea urchin fishery.
- The tribes also are seeking to resume their traditional harvests of gray whales, sea otters, and pinnipeds.
- Marine mammal assessments of the status of and trends in stocks will continue.
- The decline in Steller sea lions in Alaska heightens the importance of their numbers in Washington and Oregon, where populations are more stable.

There are also a number of considerations in planning and setting priorities for marine mammal research. There are multiple overlapping jurisdictions, responsibilities, and interests. The U.S. Fish and Wildlife Service is mandated to enforce the Endangered Species Act and has a mandate to study sea otters, while the National Marine Fisheries Service enforces the Marine Mammal Protection Act and has its own research mandates. Other parties with regulatory responsibilities and research mandates include the tribes, state agencies, the Olympic National Park and Marine Sanctuary, the universities, and private research groups. Cooperation is the key to making research and regulation effective.

Physical Oceanography of the Olympic Coast

Barbara Hickey, University of Washington School of Oceanography

Currents along the Washington coast are embedded in the larger-scale California Current system, an eastern boundary current which flows southward for several hundred kilometers along the U.S. West Coast. The coastal currents undergo seasonal variations, with the northward-flowing Davidson Current forming near shore along the northern stretches of the West Coast, including Washington, in the winter. Superimposed on this mean seasonal pattern are wind-driven fluctuations having the spatial and temporal scales of weather systems, i.e. several hundred kilometers in extent and lasting three to four days.

During spring and summer, current fluctuations on the Washington coast are also driven by the wind field off Oregon and California, which produces elevation differences in sea level that propagate northward up the coast. These currents are of the same magnitude as the mean currents, i.e., 0.5 to 1 knot. Tidal currents, having a speed of about 10 cm/sec (=10 km/day), are about one-third the speed of the wind driven currents. The tidal currents are significantly faster, however, at estuary mouths, such as Grays Harbor, Willapa Bay, and the mouth of the Columbia River. In addition to the variability described above, longer-term interannual variability in current speeds is driven by larger-scale processes such as El Niño.

The coastal winds also drive the coastal upwelling system, which is critical to biological productivity. Colder, denser, nutrient-rich water is transported upward toward the surface near the coast and then offshore during periods of northerly winds. The upwelling develops and decays on the same time and space scales as the surface winds and currents, i.e., over a couple of days and several hundred kilometers.

We would expect considerable small-scale complexity in the coastal circulation within the Sanctuary because of numerous features such as the outflow from the Strait of Juan de Fuca and the other estuaries, submarine canyons such as the Juan de Fuca and Quinault canyons, and coastal promontories such as Cape Elizabeth. The low-salinity plume from the Strait of Juan de Fuca can extend southward into the northern waters of the Sanctuary, and there is the suggestion that it induces some northward flow along the coast even when the flow elsewhere is southward. Evidence from satellite photos suggests that upwelling may be enhanced downstream of coastal promontories. The

upwelling plumes appear to extend out onto the shelf as features called “squirts” and “jets.”

Submarine canyons probably have significant biological effects. Studies elsewhere have shown enhanced productivity, more frequent whale sightings, and more intensive fishery activity in the vicinity of canyons, which are believed to create eddies that concentrate prey. During upwelling conditions, upward transport is estimated to be ten times stronger over canyons than over a shelf edge without such features. The deeper water does not reach the surface, but is entrained downstream onto the shelf, where it likely enhances productivity.

The Columbia River plume can have important effects on currents, water properties, nutrients, and productivity along the Washington coast, and is a unique feature of this Sanctuary. On average, the plume travels offshore and southward in summer, and hugs the coast to the north in winter. However, the position of the plume changes rapidly as wind direction changes, and must be considered when designing sampling programs. Currents are diverted around the perimeter of the Columbia plume, changing daily. The Columbia also creates its own currents of 10–30 km/day, on which the wind-driven currents are superimposed. There are sufficient data to begin to model these interactions.

Most current measurements have been made off the southern coast rather than in Sanctuary waters. There has never been a complete annual survey of Washington coastal currents or water properties at any location off the Washington coast. At present, NOAA has a waverider buoy off Grays Harbor and a temperature buoy off the mouth of the Columbia. I have a current meter mooring deployed off Grays Harbor at the present time (if it hasn’t been fouled by fishing gear). There also has been little work, especially in the last 20 years, on the biological effects of the Columbia plume.

In summary, the large-scale wind-driven circulation processes are reasonably well understood along the Washington coast, especially the alongshore currents. The effects of the Strait of Juan de Fuca, submarine canyons, coastal promontories, and plumes from coastal estuaries are poorly understood and potentially very important to the Sanctuary. At this time there are no mathematical models of regional coastal circulation.

(Dr. Hickey showed a videotape made in 1984 illustrating temporal fluctuations in currents at three depths near the mouth of the Strait of Juan de Fuca. In addition to showing rapid variability in current speeds and directions, the video showed prolonged intrusions of surface ocean water into the Strait against the prevailing estuarine outflow during winter storm events.)

Biological Oceanography, Contaminants, and Harmful Algal Blooms in Coastal Waters

Rita Horner, University of Washington School of Oceanography

Biological Oceanography

Barbara Hickey has discussed the physical oceanography, so I will simply reiterate that physical processes are crucial to determining productivity in the pelagic zone. The most important physical processes in the Sanctuary waters are:

- the seasonal pattern of solar radiation;
- the northerly winds in spring and summer that drive upwelling of nutrient-rich water and replenish the nutrient (primarily nitrate) content of water in the euphotic zone;
- the resulting sustained high standing stock and productivity of phytoplankton throughout the growing season.

Most of the data on the biological oceanography of the Washington coast come from cruises funded by the old federal Atomic Energy Commission and its successors, the Energy Research and Development Administration and the Department of Energy, between the early 1960's and the early 1980's. Most of the samples were taken as single stations or transects during the summer and fall.

Coastal Zone Color Scanner (CZCS) satellite observations reveal that chlorophyll concentration (phytoplankton biomass) is high over the middle shelf, intermediate over the slope, and low in oceanic waters. Productivity values have a similar relative ranking.

CZCS data also show that chlorophyll is patchy both along shore and across the shelf. There can be low levels of chlorophyll near shore, a region that is poorly represented in shipboard studies. So-called "squirts" and "jets" and localized upwelling, induced by features such as headlands and submarine canyons, increase the heterogeneity of the neritic environment and may transport chlorophyll-rich patches along or off the shelf. Potentially serious errors can be made in attempting to characterize the shelf from single stations or transects.

Even less is known about zooplankton biomass and production than about phytoplankton. Zooplankton biomass varies seasonally, interannually, and with distance

from shore. This variability reflects the spatial and temporal pattern of coastal upwelling and primary production, and to longer-term and larger-scale processes such as El Niño.

The most important zooplankton organisms on the shelf are copepods, especially the naupliar and copepodite stages, while microzooplankton appear to be most important near shore and offshore. Protozoans and larvaceans, some of the dominant microzooplankton, preserve poorly in water samples, so relatively little is known about them, and their ecological importance has only recently been realized.

It appears that most primary productivity over the Washington shelf is utilized by consumers on-site rather than being exported offshore. Consumers over the shelf enjoy a continuous food supply during the growing season. The production consumed by microzooplankton regenerates nutrients more readily than that consumed by larger zooplankton, whose fecal pellets sink quickly out of the euphotic zone.

Contaminants in Coastal Waters

In general, contaminants in sediments remain close to their sources. On the Washington coast, there is little evidence of contamination, but there are few data on which to base any conclusions. Most sediments off the Washington coast accumulate on the continental shelf, mainly between the Columbia River and Quinault canyon, with some material transported down the canyons. These sediments carry low levels of radionuclides, but higher levels of polynuclear aromatic hydrocarbons (PAHs) discharged by aluminum smelters on the lower Columbia. Some types of contaminants reach the ocean by long-distance atmospheric transport and air-sea exchange. Because of the great distance across the Pacific, this transport is not believed to be important along the Washington coast, although there is some evidence in western Canada of PCBs transported from Asia.

Hydrothermal vents at the Juan de Fuca Ridge off the Washington coast are outside of the Sanctuary, and the vent discharge probably has no noticeable effect on water or sediment quality on the shelf or slope.

Organisms can affect the nature and distribution of some contaminants. Bacteria are known to transform both inorganic and organic contaminants. Benthic organisms affect sediment distributions of contaminants through bioturbation. There are few data on concentrations or distributions of contaminants in nekton tissues.

One species of surf-zone diatom that grows along the Washington coast, *Chaetoceros armatum*, contains aluminum, lead-210, and polonium in its clay coat.

These metals originate from precipitation in fall and winter and from upwelled ocean water in summer. The metal content of surf zone diatoms may be important because these species are the primary food of the razor clam.

Dimethyl sulfide (DMS) is secreted by the phytoplankton genus *Phaeocystis*, which is observed in two forms; globular clusters visible to the naked eye, or naked cells that are very difficult to identify. DMS oxidizes in the atmosphere to form sulfuric acid and becomes a component of acid rain. DMS also contributes to cloud formation and thus is believed to affect local and possibly global climate. The abundance of this genus in Washington coastal waters is uncertain.

Harmful Algal Blooms

About 50 of the more than 5000 known species of marine phytoplankton produce toxins or kill organisms in other ways. The most well-known phenomenon is paralytic shellfish poisoning (PSP), which was first observed on the West Coast of North America during Vancouver's expedition in 1793 at what is now Poison Cove, British Columbia, where one sailor died. More than 100 Aleuts died on Baranof's expedition in 1799 in what is now Peril Strait, Alaska.

PSP is commonly called "red tide," an imprecise term because there is usually no discoloration of the water when toxins are present, in part because there are too few cells in the water and the blooms are subsurface. Furthermore, the most spectacular seawater discolorations in this area are caused by *Noctiluca*, a non-toxic single-celled grazer which eats anything it can (mainly phytoplankton, but also nauplii and eggs). When nitrogen is present, *Noctiluca* can secrete ammonia, which can be toxic to fish in high concentrations and can cause anoxia when a large bloom decays in a confined area.

Some phytoplankton species can still be harmful despite secreting no known toxin. A small number of the 30–50 local species of the diatom genus *Chaetoceros* have large cells with sharp barbed spines (setae). When *Chaetoceros* blooms occur in waters where fish are held in net-pens, the spines irritate the gills, and the resulting mucus production can cause suffocation.

Toxins produced by phytoplankton are potent, tasteless, odorless and colorless, and heat- and cold-stable, and they move easily to higher trophic levels. PSP is caused by saxitoxin and its derivatives, which are secreted locally by *Alexandrium catenella*, a dinoflagellate that usually (but not always) occurs as easily identified chains of cells.

The Washington coast was recently (1991) introduced to Domoic Acid Poisoning (DAP), the first known toxicity problem associated with a diatom. Some species of the genus *Pseudo-nitzschia* produce domoic acid, which causes gastrointestinal distress, and, in large doses, permanent short-term memory loss and even death. *P. australis* was identified as the toxic species in the 1991 outbreak in California, and both *P. australis* and *P. multiseries* are found in Washington. However, neither species has been conclusively linked to toxicity in Washington razor clams. The genus is easily identified as chains of needle-like cells, but positive species identification requires electron microscopy.

Toxic blooms of all types can be difficult to detect, because they can be very patchy and often come and go in a few days. However, some blooms can be very persistent—DAP-toxic mussels were observed for eight weeks in Hood Canal during fall, 1994.

Data Needs

The following are highlighted as data needs for research in biological oceanography, chemical contamination, and harmful algal blooms:

<u>Biological Oceanography</u>

- Species distribution and abundances (phytoplankton and zooplankton)
- Update productivity information
- Examine the interactions with fisheries
- Examine interactions with benthic community, including intertidal organisms

<u>Chemical Contaminants</u>

- Contaminant sources
- Concentrations of chemical contaminants in sea water and sediments
- Availability of contaminants in sediments to organisms
- What happens to contaminants in the organisms?
- Atmospheric fluxes both off the coast and in coastal areas

<u>Marine Toxins</u>

- Biology of causative species; spatial and temporal distributions & abundances
- What causes blooms?
- What causes cells to make toxins?
- How do toxins affect marine food webs in this area?

Water Quality Monitoring in the Olympic Coast National Marine Sanctuary

Jan Newton, Washington Department of Ecology (WDE)

My talk has the following objectives:

- To differentiate types of environments in and near the Sanctuary;
- To identify the information that water quality monitoring can yield in these environment types;
- To show what the present water quality monitoring program by WDE addresses;
- To summarize what we can learn about water quality in the Sanctuary.

We can differentiate the coastal waters of the Sanctuary from three other neighboring types of marine water bodies: the Strait of Juan de Fuca, the coastal estuaries of Grays Harbor and Willapa Bay, and Puget Sound.

I define water quality broadly as a description of the physical, chemical, and biological condition of the water. Water quality, as thus defined, is affected by inputs of fresh water and its dissolved constituents, by terrestrial inputs, atmospheric forcing, and aeolian deposition. The Sanctuary is fortunate in having a relatively clean source of air from the Pacific Ocean to the west.

This definition of water quality is different from some, which specify only a few physical and chemical properties such as temperature, pH, and dissolved oxygen concentration. The range of measurements needed to fully evaluate water quality includes the following (* indicates measurements WDE does not perform):

- Physical parameters to define environmental conditions and stability—temperature, salinity, density, currents*, light penetration and transmission
- Chemical constituents—nutrients, dissolved oxygen, metallic and organic contaminants*
- Biological components—phytoplankton biomass (chlorophyll *a*), species, and production; bacterial and zooplankton biomass*, species*, and production*; fecal coliform bacteria

More extensive water quality monitoring and research could give us greater understanding of many features of waters in the Sanctuary and in the neighboring water bodies. Below I list important features and processes about which water quality research would help us learn more.

Coastal waters

- long-term environmental trends
- upwelling impacts and dynamics
- ENSO (El Niño–Southern Oscillation)
- system dynamics (e.g., how variable is the system?)
- coastal habitats (define regimes that organisms inhabit)
- dynamics of planktonic species, particularly those causing harmful algal blooms

Strait of Juan de Fuca

- interchange between Pacific coast waters and Puget Sound waters
- effects of input to and output from Puget Sound with respect to temperature, salinity, nutrients, and contaminants
- importation of exotic species

Coastal Estuaries

- effects of different forcing and dynamics than either Puget Sound or East Coast estuaries
- unique environmental problems (e.g., *Spartina* invasion)
- relative vulnerability to degradation as related to lesser complexity and smaller basin areas compared to Puget Sound

Both Puget Sound and Willapa Bay are the subject of ongoing water quality studies by WDE. These studies have enabled us to draw several comparisons between the two estuaries. The distinctive features of the pelagic biology on Willapa Bay are listed below (* indicates a significant difference from Puget Sound):

- It is strongly influenced by the physical environment
- *There is a strong influence from river input.

- Light transmission in the water column is strongly affected by the sedimentary load of river input as well as by biologically–derived particles; there is the least light transmission near river mouths.
- *The light environment is highly variable and the euphotic zone tends to be shallow.
- *Both nitrogen and phosphorus nutrients may limit primary production.
- *Diatoms appear to be numerically dominant over dinoflagellates year-round.
- Fecal coliform contamination of the water column is seen consistently near the town of Raymond.

The Washington Department of Ecology's Ambient Monitoring Program, which conducts these studies, has the following goals:

- To characterize the spatial and temporal patterns of ambient marine water quality in Puget Sound and the coastal estuaries;
- To identify significant changes in water quality that may indicate environmental changes or emerging problems, being sure to distinguish natural from anthropogenic effects;
- To provide and maintain a long-term water quality database to serve the public and to support researchers and other agencies.

WDE has monitored water quality in these water bodies since 1973. The Environmental Protection Agency's Initiative on Ecosystem Management has chosen Willapa Bay as a model coastal estuary, and recently awarded WDE a grant to study water quality and nutrient and production cycles there.

Water quality is not routinely monitored in the Sanctuary, nor in the Strait of Juan de Fuca, because the logistical difficulties outweigh the perceived need. (Canada sometimes conducts work in the Strait.) From what we know, this area is probably not highly sensitive to degradation of water quality. Nevertheless, one could question the wisdom of leaving these waters unmonitored. Monitoring of coastal and Strait waters would gain baseline data on water quality trends, data that could be used in models. It would also provide data on boundary conditions between the ocean and the coastal estuaries, and between the Strait and Puget Sound, which would enhance our understanding of the water bodies that we are currently monitoring.

If water quality studies were undertaken in the Sanctuary and neighboring waters, a two-fold approach would be useful. First, moorings could be deployed with a battery of instruments for monitoring both physical parameters (e.g., temperature, salinity, winds, currents, and light transmission) and biological properties (e.g., dissolved oxygen, nutrients, and spectral composition). At present, only one mooring is deployed along the coast, off the mouth of the Columbia River. The second strategy would be to conduct intensive, short-term time-series cruises, which don't tell much about trends, but are very useful for studying processes.

Coastal Sediments of the Olympic Coast

Chris Sherwood, Battelle Marine Sciences Laboratory

I will begin with a review of the background geology of the Washington coast. The coast generally exhibits coarse sediments and rocky substrates. However, gravel deposits are uncommon, and the sediment veneer is very thin. Washington has an active continental margin, meaning that there is a narrow shelf, coastal mountains, and seismic activity. In addition, sea level is currently dropping along the coast as the land is experiencing tectonic uplift. The coast is varied, with cliffs and pocket beaches to the north, and barrier beaches to the south. This is a high-energy coast, with heavy wave action and wind-driven currents. The coastal waters are biologically productive and relatively pristine.

Coastal sediments originate from several sources. Beaches and river channel sediments represent relict low-stand deposits such as glacial outwash. They also include some material eroded from coastal deposits, including bedrock and Pleistocene deposits. The sediment supply to the shelf is moderate to low. Shelf sediments derive mostly from rivers, with all sediment sources north of Grays Harbor contributing only 10^{-5} as much sediment as the Columbia River. (The Chehalis River may have been much more important as a sediment source during the immediate post-glacial period.) Some shelf sediment also is derived from biological and chemical processes.

There are relatively few long-term data on the fate of sediments on the shelf. The net direction of sediment transport is northward, and most transport occurs during winter. The path of riverborne ash from Mt. St. Helens revealed that sediment is transported northwestward across the shelf from the Columbia, and tends to move down the Quinault Canyon. The predominant sedimentary feature on the shelf is the mid-shelf silt deposit, which overlies transgressive sand laid down as sea level rose following the last glaciation. The silt deposit is 14 meters thick off Grays Harbor and accumulating at a rate of about four millimeters per year. The thickness and accumulation rate are about half of that in Sanctuary waters.

Focus Group Discussions

The focus group discussions were designed to obtain and organize the knowledge of groups of researchers who have experience in Olympic coastal waters (see Introduction). The main task of the groups was to identify and discuss priority topics and procedures for future research to be conducted in the Sanctuary.

Six groups were designated to encompass the range of research needs and possibilities in the Sanctuary. Each group was facilitated by one or more individuals, who presented its results to the larger group at the end of the workshop. The scope of each group roughly corresponded to one of the topics of the plenary talks.

- Intertidal, Subtidal, Estuarine, Kelp & Seagrass Ecology (M. Dethier, T. Mumford, A. Shaffer)
- Nearshore Fish, Shellfish & Aquaculture (D. Simons)
- Seabirds (J. Parrish)
- Marine Mammals (P. Gearin)
- Oceanography, Geology, Biotoxins, Contaminants (J. Newton)
- Historic & Prehistoric Uses, Archaeology (L. Stilson)

The groups were asked to consider and respond to the following questions:

1. What are the current and future uses of and demands or stresses on the marine environment?
2. What existing research activities are underway, and how would you summarize their findings?
3. What are management concerns and issues compiled from previous conferences?
4. What research is necessary, both basic and applied?
5. What opportunities exist for collaborative research efforts and standardizing protocols? How can we plan future research to increase coordination and efficiency?

The raw results of the group discussions are organized into a series of tables (Tables 2-5), one table addressing each of the five questions above. The points noted by each of the six groups are sorted according to topic and presented in parallel columns. A number of generalizations can be drawn from the focus group results presented in Tables 2-5. These generalizations are set forth below by first describing the context of current stresses and management concerns (Table 2), then reviewing the existing research and additional research needs (Tables 3-5). Similar results of two focus groups have been combined in Tables 2 (Nearshore Ecology and Shellfish) and 3 (Seabirds and Marine Mammals).

Some participants expressed concern that the depth of their discussions may have been limited by the small group size of their focus session. Accordingly, in some groups, the research specialties of participants may not have covered the full scope of relevant expertise that would have been ideally desired.

Current Stresses and Management Issues

The current uses of and stresses on the marine environment in the Sanctuary, and especially the issues that demand management responses (Table 2), set the context for defining research needs in the Sanctuary. They are categorized into issues relating to impacts from the following sources: resource harvesting, recreational use, anthropogenic contamination, habitat alteration, and natural processes and variations. An additional category in Table 2 includes general recommendations for improved management.

The harvest-related stresses and management concerns mostly widely cited by the focus groups arise from three principal sources:

- commercial and recreational harvests of nearshore invertebrates and algae (commercial and sport fisheries take place within the Sanctuary but are not under its jurisdiction);
- conflicts between offshore commercial fisheries and seabirds and mammals, such as the incidental taking of birds and mammals in gill-nets and the interference in fishing operations by mammals;
- proposed renewed tribal harvesting of mammals (particularly gray whales) as a traditional subsistence use.

The shellfish, mammal, and archaeology groups all recommended studies of past harvests and present harvest demands of these resources by native tribes and other

groups, and of how these harvests both relate to the cultural needs of the tribes and interact with non-tribal harvests. Some potential stress was also cited by the focus group members associated with the current and anticipated expansion of non-consumptive "ecotourism" activities such as whale-watching and sight-seeing. The main potential impact of the latter activities is disturbance of feeding and breeding grounds of seabirds and mammals.

The primary concern cited by the groups related to anthropogenic contamination was the threat of a major oil spill, and the preventive and responsive measures that managers should consider to address that threat.

The groups cited three predominant types of issues related to habitat alteration:

- coastal impacts resulting from upland land- and water-use practices, including forestry, agriculture, and waste disposal;
- coastal erosion and other sediment dynamics, along with human responses such as shoreline armoring;
- invasion by exotic species.

The focus groups also listed several types of natural processes (or quasi-natural processes—large-scale, diffuse anthropogenic effects originating outside of the Sanctuary) that may affect managed resource populations. These processes include:

1) the life histories, populations, and distributions of marine mammals, some of which are threatened or endangered and demand close management scrutiny;

2) the role of the nearshore environment in the life histories of harvested, scarce, or keystone marine species, such as marbled murrelets and other seabirds, baitfish, salmonids, and crab;

3) natural or quasi-natural environmental perturbations such as earthquakes and tsunamis, coastal erosion, biotoxin outbreaks, El Niño, and climate change.

Existing Research and Research Needs

The overview of existing research and recommendations for future research by the focus groups are categorized by group and category in Tables 3–5. Table 3 summarizes existing and past research; Table 4 summarizes recommended research, and Table 5 presents identified needs for data exchange among the research disciplines represented by the focus groups. Existing and past research generally is not included in the table unless it was cited by the focus groups.

The categories of research selected are based on the three types of research used as a framework for management in the Olympic Coast National Marine Sanctuary Final Environmental Impact Statement (NOAA 1993; Appendix 1): baseline studies, monitoring, and predictive studies. Additional categories are included to encompass the range of discussions conducted in the focus groups. The discussion below reviews these needs in the context of existing research and the stresses and management concerns outlined above.

Baseline Studies

The focus groups identified only a limited amount of baseline research that has been or is being conducted in the Sanctuary (Table 3). Most of research identified appears to have been concentrated in the nearshore area, except for offshore bird and mammal surveys. The baseline surveys have mainly concerned habitats and harvested resources such as shellfish. (The steering committee chose not to include fishery research or fishery management issues in the scope of the workshop because these issues are dealt with in numerous other conferences and hearings.)

The sparse nature of past research in the Sanctuary is evident in the consistent citation by all groups of the need to conduct inventories of resources and to map and create centralized databases of existing, updated, and newly developed data (Table 3). The oceanography/geology/contaminants and marine mammal groups called for compiling and organizing existing information as well as initiating some new baseline studies. The oceanographers suggested a baseline aerial survey of habitats and coastal erosion, high-resolution sea floor mapping in specific areas of interest, and (together with the mammologists) a survey of anthropogenic contaminants in animal tissues and sediments. The intertidal/subtidal focus group suggested smaller-scale baseline oceanographic work near shore. The archaeology group noted that upland archaeological sites have been inventoried, but that intertidal and subtidal archaeological inventories are required.

The living resources identified most prominently as needing baseline studies fall into three categories: 1) seabird populations, especially those nesting within the Sanctuary; 2) kelp habitat; 3) the nearshore prey of marine mammals and commercial and recreational fish, especially “baitfish” (nearshore pelagic forage fish such as smelt, anchovies, sand lance, and herring); and 4) harvested shellfish such as mollusks,

crustaceans, and echinoderms (e.g., razor and hardshell clams, mussels, crab, shrimp, and urchins). Archaeological resources also were characterized as needing an inventory.

Monitoring

The groups identified considerable monitoring that is already being conducted, and recommended that these efforts be continued and expanded. These existing programs include population monitoring of seabird colonies and some mammal species, and monitoring of shellfish harvests and their population impacts. The groups recommended expansion of both programs to include such data as demographic parameters, food habits, distributions and migrations, and individual identification (banding of birds and photo-ID of whales). Biotoxins are also being monitored in shellfish, and it was recommended that these efforts be expanded by increasing their frequency and adding synoptic phytoplankton and oceanographic monitoring.

All of the focus groups recommended selecting certain sites for more intensive monitoring activities. Several specific locations were proposed (such as Tatoosh, Kalaloch, and La Push) on the basis of existing data, logistical ease, and ability to serve as a representative site for a larger area. The intertidal/subtidal group highlighted the lack of knowledge about estuaries in the Sanctuary. The seabirds, mammals, and oceanography groups all highlighted the presumed existence of "hot spots," where ocean conditions may create especially favorable feeding conditions, as targets for research and monitoring. The location of potential sites is unknown. It might be possible for a smaller interdisciplinary working group to choose a consensus site (and protocol) that would serve the monitoring needs of all the research specialties.

The oceanography group divided the Sanctuary into three monitoring regions as part of a call for an ambitious new oceanographic monitoring program using offshore buoys, satellite observation, and hydrographic surveys of the coast. The oceanography and mammal groups recommended ongoing monitoring of anthropogenic contaminants in animals and sediments after completing the recommended baseline study. The archaeological group recommended monitoring of erosion at known archaeological sites.

Predictive Studies

Predictive studies reveal the underlying natural processes that control changes in the environmental variables that are observed in baseline and monitoring studies. Most of the predictive work recommended by the focus groups involved organism- and

community-scale studies: general physiology, food habits, community interactions, reproduction, and life histories of important nearshore shellfish and other invertebrates, juvenile fish, seabirds, and mammals. The nearshore group proposed researching the linkage between nearshore geomorphology, habitat types, and biotic communities. The shellfish group also recommended studies of the processes affecting the levels and distribution of biotoxins in shellfish and baitfish.

There were also recommendations by all the focus groups to explore the broader linkages between marine and terrestrial ecosystems to address impacts of land uses on marine species such as marbled murrelets (which nest on old-growth forests) and kelp (which may be sensitive to sedimentation).

Research Methodology

As part of their discussions, each of the focus groups offered suggestions about procedures that should be followed to ensure the maximum efficiency and validity of all three types of research. The following were some common points among these suggestions:

- Develop multidisciplinary conceptual and mathematical models to integrate knowledge at the nearshore, oceanographic, and ecosystem scales;
- Develop standardized protocols and assessment methods for shellfish populations, bird populations and life histories, and contaminants in mammals;
- Employ procedures and logistics that will assure statistical reliability of research results and provide the most effective use of available funding
- Foster cooperation between agencies having a mandate on the Olympic coast. Make special efforts to work with tribal resource departments and managers, and where appropriate, involve the larger community beyond researchers, especially recreational users, in assisting research.

Table 2. Demands, Stresses and Management Issues in Focus Group Discussions

Type of Stress or Management Issue	Intertidal/Subtidal, Estuarine, Kelp & Seagrass Ecology; Nearshore Fish, Shellfish & Aquaculture	Seabirds	Marine Mammals	Oceanography, Geology, Biotoxins, Contaminants	Historic & Pre-historic Uses, Archaeology
Harvests	Maintain balance between use & protection of sustainable resources Potential commercial harvest pressure Harvested organisms: • mussels • hardshell clams (littleneck, butter, horse) • *Salicornia* • rock scallops • urchins • razor clams • rockfish • *Postelsia* • chitons/limpets • cucumbers • gooseneck barnacles • kelp • *Nucella* (dog whelks)	Interactions with fisheries, esp. gill-nets: • Political & jurisdictional problems —need cooperative agreements among relevant parties, e.g., tribes, NMFS, WDFW, USFWS • need these data to determine survivorship & migration for species population biology • not enough data on bird biology to advise managers —significance of 3,000–5,000 deaths in non-tribal fishery in 1994? —were most from much larger Oregon populations?	Fishery–mammal interactions: • incidental catch & mortality of harbor porpoise, harbor seals, and sea otters in gillnets • general impacts of mammals on fish stocks, fishing gear, & fishery economics • sea otter–shellfish & salmon–pinniped interactions Proposed tribal harvest of mammals: • seals, sea lions, gray whales & sea otters • what are management plans in effect, proposed methods and level of exploitation?	Harvestable resource & biodiversity decline • commercial & recreational species: fish, shellfish, algae • marine mammals, birds Aquaculture potential	Recognize & have tribes assess traditional harvesting practices and impacts. • Identify & emphasize activities that have zero or minimal impacts on Sanctuary resources & that are critical in maintaining a sense of community, self, or culture. • Disseminate results through public education. • Could defuse and "remove from the table" a potentially contentious issue.
Recreation	Potential recreational harvest pressure Non-consumptive human impacts (tramping, souvenirs)	Ecotourism • International issues (US versus Canada) • Guidelines for operators • Public information & education • On-boat vs. on-land human disturbance • Regulation of fishermen vs. non-fishermen	Probable increases in whale-watching eco-tours & sight-seeing Disturbance, pollution & other sport fishery conflicts	Recreation & aesthetic Education	

Table 2 (continued). Demands, Stresses and Management Issues in Focus Group Discussions

Type of Stress or Manage-ment Issue	Intertidal/Subtidal, Estuarine, Kelp & Seagrass Ecology; Nearshore Fish, Shellfish & Aquaculture	Seabirds	Marine Mammals	Oceanography, Geology, Biotoxins, Contaminants	Historic & Pre-historic Uses, Archaeology
Contam-inants	Oil RDA Trustee baseline data & recovery rates Preparation for oil spill response Sewage impacts		Oil spills & other anthropogenic sources of contaminant loading.	Shipping: oil, cargo transport	
Habitat Alterations	Alteration of normal conditions & processes: • sediment dynamics • hydrology • water chemistry • geomorphology • habitat structure (biotic & physical) • fisheries harvest Sediment dynamics & links to habitats • impacts on kelp Shoreline armoring Land use practices in watersheds Exotic species invasions			Habitat loss & alteration Upland and watershed impacts: forestry, development, agriculture, waste Coastal erosion: beaches, habitat Exotic species invasion	

Table 2 (continued). Demands, Stresses and Management Issues in Focus Group Discussions

Type of Stress or Manage-ment Issue	Intertidal/Subtidal, Estuarine, Kelp & Seagrass Ecology; Nearshore Fish, Shellfish & Aquaculture	Seabirds	Marine Mammals	Oceanography, Geology, Biotoxins, Contaminants	Historic & Pre-historic Uses, Archaeology
Natural Systems	Role of shallow subtidal and nearshore environment in life histories: • forage fish • murrelets • salmonids • crab • marine birds		Continued annual assessments of how status & trends of mammal stocks relate to all other issues Identify, describe & map critical areas, e.g. Ozette/Cape Alava Identify reasons for importance of OCNMS as a primary migration route Identify species stock structure to identify mammal sub-groups that might be affected by incidental or directed mortality Species studies: • Sea otters of primary concern • Steller sea lion issues • Humpback whale movements & offshore feeding areas Environmental stresses such as El Niño, biotoxins	Seismic & tsunami hazard Erosion Biotoxin outbreaks (domoic acid/PSP) Long-term climate & environmental change in absence of baseline data	

Type of Stress or Management Issue	Intertidal/Subtidal, Estuarine, Kelp & Seagrass Ecology; Nearshore Fish, Shellfish & Aquaculture	Seabirds	Marine Mammals	Oceanography, Geology, Biotoxins, Contaminants	Historic & Pre-historic Uses, Archaeology
Improved Management	Cost-effective management & research Credibility of research	Proactive vs. reactive management approach • see how other areas, agencies, states, etc. address this problem • inter-agency cooperation, restoration, experimentation. Link monitoring & surveys to public • beached bird (& mammal) surveys • public outreach & education		Establish baseline data & threshold values	

Table 3. Existing and Past Research

Type of Research	Intertidal, Subtidal, Estuarine, Kelp & Seagrass Ecology	Nearshore Fish, Shellfish & Aquaculture	Seabirds & Marine Mammals	Oceanography, Geology, Biotoxins, Contaminants	Historic & Pre-historic Uses, Archaeology
Recent Baseline Studies	Shellfish tribal reports (NWIFC & tribes) Site info (Dethier 1988, 1990, 1991; Dethier et al. 1989; WOodbury & Dethier 1991)) Habitat inventory & geomorphology (Schoch; Terich & McKay 1988; McKay 1990; McKay & Terich 1992) • subsidence (Atwater) Coastal video mapping (Warheit) Shallow subtidal surveys • (Carney & Kvitek 1990; Kvitek et al. 1989, in prep.) • WDFW institutional knowedge (Buckley, West, Doty) • Kelp maps (Van Wagenen 1996) • Urchins (Bradbury, WDFW) • Duncan/Dunce Rocks (Paine) • Unpub. thesis work (Paine students) • Quileute R. estuary (U.S. Army Corps of Engineers 1986) • Neah Bay (Simenstad et al. 1988) Wildlife in estuaries Midden sites (Gleeson 1980)	Limited work on nearshore pelagic planktivorous fish ("baitfish") • some synopic surveys (NMFS) • marine fish recreational survey in the 80's (WDFW) • unknown whether either survey covered the Sanctuary • co-operative seabird and hydroacoutistic survey around Tatoosh Island summer of 1995 (Parrish, UW; Lemburg, WDFW) • other contacts: Doty, Bargman, Buckley, & Pentilla (WDFW)	NOAA ship *McArthur* bird and mammal surveys (NOAA, WDFW, Cascadia Res., OCNMS) Harbor porpoise capture & satellite tag tracking studies (NMML, WDFW) MMS/Ebasco surveys (Bonnell et al. 1992, Briggs et al. 1992, Green et al. 1992)		Since 1956, of the 90 sites reported from the outer Washington coast, 13 sites have been subjected to significant levels of excavation and have been reported or, at least, have radiocarbon dates available. Currently known archaeological sites can offer extensive baseline datasets of at least 3,800 years. • The faunal remains from the Ozette site numbers over 1,000,000 specimens. • Floral and faunal data from archaeological sites can offer evidence of environmental change.

Table 3 (continued). Existing and Past Research

Type of Research	Intertidal, Subtidal, Estuarine, Kelp & Seagrass Ecology	Nearshore Fish, Shellfish & Aquaculture	Seabirds & Marine Mammals	Oceanography, Geology, Biotoxins, Contaminants	Historic & Pre-historic Uses, Archaeology
Data Archives	Eelgrass & kelp maps • Rigg & Miller (1949), Rigg (1912a, 1912b, 1915a, 1915b, 1925) • Waaddah I., Seal Rock Shallow subtidal surveys —Neah Bay (Navy 1940's) —Lie & Kelley (1970), Lie & Kisker (1970) Traditional knowledge			General sources • AEC/ERDA/DOE data (Landry & Hickey 1989) • Canadian data publ. (Hickey/IOS) • 1972 data report (G. Cannon, PMEL) • NODC • ship-of-opportunity data and interpolations (PMEL, UW?) • drifters (Ebbesmeyer) Groundfish trawl data, some in GIS (WDFW, NMFS)	Historic photos: changes & occurrences (coastal sediments, shipwrecks) GLO (Government Land Office) surveys (first probably ca. 1880) possible gross data on land forms, upland plants, shoreline changes
Natural Processes Monitoring Studies	Shellfish, esp. razor clams (WDFW) Small-scale oceanographic & sediment studies Nearshore habitat interactions Baitfish spawn surveys (intertidal)		Annual assessments of common inshore species , e.g. harbor seals, sea lions, sea otter, gray whale (WDFW, NMML, NBS, Makah Tribe) Steller sea lion distribution & abundance (NMML, WDFW, Makah Tribe) El Niño effects (Wilson 1991)	Weather/Waves • data: wind speed & direction, air & sea surface temperature, wave height & period, barometric pressure • sea surface temperature by AVHRR satellite (NOAA Coastwatch) • sites: Destruction & Tatoosh Islands, Columbia River, Willapa Bay, Cape Elizabeth buoys (NDBS) • availability: real-time from Internet, archive for 1 week (U. Florida), CD-ROM after 6 months (NDBS)	

Table 3 (continued). Existing and Past Research

Type of Research	Intertidal, Subtidal, Estuarine, Kelp & Seagrass Ecology	Nearshore Fish, Shellfish & Aquaculture	Seabirds & Marine Mammals	Oceanography, Geology, Biotoxins, Contaminants	Historic & Pre-historic Uses, Archaeology
Natural Processes Monitoring Studies (cont.)				Shellfish monitoring • PSP & ASP toxins in razor clams, mussels, other clams all year; ASP in cooked crab gut as needed (WDH, tribes) —4 sites on coast; mussels twice monthly, razor clams weekly Phytoplankton monitoring • 3 offshore sites for monitoring phytoplankton secreting domoic acid weekly for 1 year (tribes, NMFS, WDH, WDFW)	
Contamin-ation & Anthropo-genic Effects Monitoring Studies	Hydrocarbon monitoring by NOAA mussel watch & collaboration with Dethier		Mammal by-catch in Makah marine set-net fishery (NMML, Makah Tribe) Tests of acoustic devices to mitigate by-catch of harbor porpoise & other mammals in Makah set-net fishery (NMML, Makah Tribe)	Water quality monitoring • surface temperature, salinity, & fecal coliform bacteria monitored monthly Grays Harbor, Willapa Bay, Quinault beach, Neah Bay; • shoreline surveys of fecal coliform sources (WDH) Watershed Water Quality • Quillayute River from headwaters to mouth (multiple agencies) • watershed info & analysis (WDE)	

Table 3 (continued). Existing and Past Research

Type of Research	Intertidal, Subtidal, Estuarine, Kelp & Seagrass Ecology	Nearshore Fish, Shellfish & Aquaculture	Seabirds & Marine Mammals	Oceanography, Geology, Biotoxins, Contaminants	Historic & Pre-historic Uses, Archaeology
Contamin-ation & Anthropo-genic Effects Monitoring Studies (cont.)				Contaminant Loading • sampling of marine mammal tissues for contaminants (Makahs, NOAA) • Oil spill studies • Canadian studies (UBC, IOC, U Vic) in Strait of Juan de Fuca • NPDES permits, EIS & restoration & building plan permits (ACE, EPA, state agencies) Ocean discharge criteria • required by Minerals Management Service • Grays Harbor dredging permits required by ACE • Clark et al. (1978), Strand et al. (1992)	
Predictive Studies	• Surface water transport by drift cards (Ebbesmeyer) • Kinnetics (1992) study at Two-Bit Point • Sea otter foraging (Krause) • Makah reservation (Paine 1980, 1986; Paine & Levin 1981; Paine & Vadas 1969) • Surf diatoms (Lewin) • *Phyllospadix* genetics (Ruckelshaus & McFadden)		Sea otter captures, biology, tracking (NBS, WDFW) Steller sea lion diet, migration (NMML, WDFW, Makah Tribe) Gray & humpback whale photo ID, feeding locations, habitat use (Cascadia, NMML, OCNMS)	Sediment Transport & Beach Processes • M.S. theses on Olympic Coast (Terich & McKay 1988; McKay 1990; McKay & Terich 1992) • littoral sand transport (Schwartz & Mahala 1984, 1985; Schwartz & Bronson 1984a & 1984b; Schwartz & Bubnick 1984)	Gearhart et al. (1990) underwater predictive modeling (MMS)

Table 4. Recommended Research

Type of Research	Intertidal, Subtidal, Estuarine, Kelp & Seagrass Ecology*	Nearshore Fish, Shellfish & Aquaculture*	Seabirds	Marine Mammals	Oceanography, Geology, Biotoxins, Contaminants	Historic & Pre-historic Uses, Archaeology
Baseline Studies	1. Inventory of shallow subtidal benthic, planktonic, & juvenile fish communities • baitfish use & spawn distribution 3. Inventory estuaries associated with streams in Sanctuary, e.g., Quillayute	1. Basic inventory of species & habitats: • Include aerial mapping & GIS. • Nearshore pelagic "forage" fish ("baitfish") populations—surf smelt, night smelt, anchovies, sand lance, & herring. —of interest to multiple agencies & tribes as a food source & for recreational catch. —of interest to federal agencies because of mixed stock issues and stock movement between the U.S. & Canada • Smelt spawning habitat, including: —presence/absense of smelt spawn —catalog probable beach areas —sample monthly year-round because of multiple species —aerial mapping of probable beach areas	1. Seabird census data are lacking at sea & at breeding colonies & nest sites • At colony/nest site, band birds if possible without excessive disturbance Assemble multiple regional seabird database and publication repositories with groups such as PSG, Washington ad hoc Seabird group, OCNMS.	Inventory & map existing data. • Much of the information now being used is outdated. • Establish & maintain database including historic & archaeological data (NMFS, WDFW, OCNMS, others) Identify & map critical habitats & areas of special interest ("hot spots"). Identify data gaps. —Example: areas susceptible to oil spills. —Example: offshore areas related to marine features, e.g., upwelling • Baseline environmental contaminant data	Get data archives: entrance to Strait of Juan de Fuca, off (south of) La Push, Cape Elizabeth, Copalis (begun by WDFW, NOAA, OSU) • habitat classification • geomorphic features High-resolution sea floor mapping in areas of specific interest • improve view of entire Sanctuary • improve understanding of wave refraction & upwelling • address habitat and sediment inventory and establish baseline • study oil spill impacts • Focus area A • Columbia River mouth (channel & marina) • subtidal & intertidal areas	Complete basic inventory of archaeological sites: • canoe runs, fish weirs, fish traps, & historic piers, wharves, trash dumps, petroglyphs, transportation routes, fords, ferries, etc. Inventory of the cultural resources of the offshore islands. Special sensitivity is needed because of possible burials. Inventory of existing research activities and summary of findings.

*Numbers (where present) indicate priority assigned research category. Lack of number indicates no priorities assigned.

Table 4 (continued). Recommended Research

Type of Research	Intertidal, Subtidal, Estuarine, Kelp & Seagrass Ecology*	Nearshore Fish, Shellfish & Aquaculture*	Seabirds	Marine Mammals	Oceanography, Geology, Biotoxins, Contaminants	Historic & Pre-historic Uses, Archaeology
Baseline Studies (cont.)		1. Inventory of species & habitats (cont.): • Shellfish: commercial, recreational, & tribally harvested species, e.g., Dungeness crab, pink shrimp, razor clams, hardshell clams, mussels, urchins • Outer shelf groundfish & salmon (B. Culver, WDFW) 2. Historic & pre-historic use of area baitfish & shellfish by tribal and non-tribal users (literature search & interview) • cultural needs of coastal tribes 3. Basic life histories of many species • Nearshore kelp canopy nursery ground for juvenile fish • Scuba surveys currently used in Puget Sound (WDFW) • multiple agency & tribal interest (NPS, (NWIFC, WDFW)			Continuous aerial coastline survey to address erosion & habitat issues & resource inventory & to establish baseline Contaminant surveys to obtain baseline species & habitat information: • tissue contaminant & biomarker concentrations for a few species —in-situ contam-inants in life-long inhabitants (English sole, crabs) —contaminants imported by migrants (e.g., birds, mammals) —opportunity-based • spatial distribution of sediment contamination profiles for selected sites —shallower waters —seasonal coverage —site-specific along entire coast, e.g., 2 sites in each regime	

*Numbers (where present) indicate priority assigned research category. Lack of number indicates no priorities assigned.

Table 4 (continued). Recommended Research

Type of Research	Intertidal, Subtidal, Estuarine, Kelp & Seagrass Ecology*	Nearshore Fish, Shellfish & Aquaculture*	Seabirds	Marine Mammals	Oceanography, Geology, Biotoxins, Contaminants	Historic & Pre-historic Uses, Archaeology
Monitoring Studies	5. Intertidal & shallow subtidal zone: • harvests of shallow subtidal and intertidal razor clam and other species: numbers, impacts, maximum sustainable yield	4. Investigate marine toxins • shellfish —seasonality determination —toxin level monitoring —multiple toxin studies (PSP, ASP & DSP "diuretic shellfish poisoning") —location deviations of toxin concentrations	Continue existing long-term on-colony monitoring of population trends & demographic & life-history data (e.g., food habits); —will require ability and permission to band birds • Because of inherent population variability, detecting population trends requires LONG-TERM monitoring building on existing studies • Expand (in time) initial collaborative monitoring at sea, including adult-juvenile ratios —to estimate productivity (e.g., marbled murrelets) —to complement on-colony productivity data (e.g., murres). • Determine causes of change, i.e., physical and biological factors in the environment	Ongoing species inventories, status and trends surveys: • Continued population monitoring —Sea otters: population, tracking, benthic community relationships —Steller sea lion: diet, movements and migration, fishery interactions —Gray whale: radio tracking, continued photo ID, and biopsy studies to determine numbers & movements of "summer residents" (potential harvest impacts) —Humpback whale: distribution, photo ID —Harbor porpoise: assessments, stock structure, movements (fisheries impacts) —Northern fur seals: migration, food habits —River otters —Offshore cetaceans & sea turtles: distribution & abundance • Strandings, beach walks	Monitor Strait of Juan de Fuca (Focus area C) by buoy to address environmental trends, habitat, & ENSO for additional model input Increase biotoxin surveys to weekly • one site, e.g., Kalaloch or Tatoosh • ID phytoplankton species, including surf diatoms (USCG, ships of opportunity?) • onshore transect • monitor conditions at a mooring 20–30 miles offshore (NOAA buoy Cape Elizabeth) Monitor circulation, environmental conditions, & erosion • Doppler & CTD surveys of entire coast • Satellite circulation data (Focus area C) • seasonal (e.g., quarterly) data • establish and collect database • Issues: spatial patterns in circulation, local upwelling, effect of Strait of Juan de Fuca & fresh water	Monitor erosion of coastal sites.

*Numbers (where present) indicate priority assigned research category. Lack of number indicates no priorities assigned.

Table 4 (continued). Recommended Research

Type of Research	Intertidal, Subtidal, Estuarine, Kelp & Seagrass Ecology*	Nearshore Fish, Shellfish & Aquaculture*	Seabirds	Marine Mammals	Oceanography, Geology, Biotoxins, Contaminants	Historic & Pre-historic Uses, Archaeology
Specific Monitoring Sites		6. Select limited major study sites for each discipline. Tatoosh, Kalaloch, additional area in the southern sanctuary.	Choose sites that are: • in existing refuges, parks & Sanctuary • logistically friendly • cost-effective • represent a range of key habitats & species Sites should include: • on-colony and at-sea • nearshore/offshore • tribal and non-tribal • forest habitat for marbled murrelet & harlequin duck • examples: Tatoosh already a long-term site; refuge islands surveyed for surface nests (Protection, Destruction, Smith, possibly Colville) Identify key species by criteria such as: • food chain approach • bioindicators (range of species with differing sensitivities, especially to anthro-pogenic effects) • rare; concern exists for their survival • existing baseline data		Focus sites A: La Push sediments B: Kalaloch biotoxin) C: Physical & Biological Regimes #1 Northern tip to La Push (get buoy) #2 La Push to Cape Elizabeth to Copalis (keep existing buoy) #3 off Strait of Juan de Fuca • D: Tatoosh & south/north of La Push (kelp beds)	1. Locate inundated villages, campsites, & locations • use underwater predictive modeling with subsequent testing by sediment coring along submerged embayments, river valleys, lee shores of islands, Lake Ozette (possible former estuarine embayment) • questions include whether colonization followed coastal or interior routes, nature & antiquity of human adaptation to marine resources on the Pacific Coast. Continue remote sensing efforts to locate shipwrecks and submerged planes.

*Numbers (where present) indicate priority assigned research category. Lack of number indicates no priorities assigned.

Table 4 (continued). Recommended Research

Type of Research	Intertidal, Subtidal, Estuarine, Kelp & Seagrass Ecology*	Nearshore Fish, Shellfish & Aquaculture*	Seabirds	Marine Mammals	Oceanography, Geology, Biotoxins, Contaminants	Historic & Pre-historic Uses, Archaeology
Predictive Studies	5. Intertidal & shallow subtidal zone: general biology of razor clams, other species Impacts of oil and oil remediation methodologies	4. Investigate marine toxins • shellfish uptake & depuration studies —multiple toxin studies (PSP, ASP & DSP "diuretic shellfish poisoning") • baitfish important because of proven interaction with some pelagic nearshore fish such as anchovies (California, 1991) • also may be interactions with marine mammals and man	• Life history parameters at colony/nest site —genetic and morpho-metric research VERY IMPORTANT (WA, OR, perhaps BC, AK) —survival —age at which birds return to colony/first breed —reproductive success (laying, hatching, fledging) —foraging (link to at-sea parameters): food to chick (frequency, abundance, species); growth, energetics of chicks —community ecology (e.g., predator-prey interactions, exotic species effects) • population numbers at nest / attendance • reproductive biology, including phenology • gene flow (genetic isolation, immigra-tion, emigration) • toxicology: biological & anthropogenic	Species-specific areas for priority research: a/ Ecosystem Effects • Food consumption & Diet models —More information on diet is needed and food consumption models are required to estimate possible effects of mammals on prey stocks. b/ Health • Blood baselines, disease screening —Health screening by blood serology or through tissue sampling. c/ Resource Utilization • Tribal harvest needs & concerns • Fisheries conflicts —Fishery interaction/by-catch mitigation studies • Ecotourism effects	Kelp-sediment interactions (Focus area D) • Methods: • bathymetry and side-scan sonar • update historical surveys • characterize sediments • archeological resources	Overview research on past, present, & future human role in the Sanctuary, including: • individual, group, & community roles • all ethnic user groups (Native American, Euro-American, Hispanic, Asian-American) • how sanctuary resources contribute to community values. Assessment of how local communities depend on coastal resources. • how people see and relate to their environment • what Sanctuary resources were utilized in the past? • what resources are currently being utilized? Use tribal oral histories to explain, and possibly date, geological occurrences. • e.g., Makah tradition of a "great flood"

*Numbers (where present) indicate priority assigned research category. Lack of number indicates no priorities assigned.

Table 4 (continued). Recommended Research

Type of Research	Intertidal, Subtidal, Estuarine, Kelp & Seagrass Ecology*	Nearshore Fish, Shellfish & Aquaculture*	Seabirds	Marine Mammals	Oceanography, Geology, Biotoxins, Contaminants	Historic & Pre-historic Uses, Archaeology
Predictive Ecosystem Studies	Link with watershed planning	5. Need to correlate multidisplinary studies to set broader research goals with more impact.	• Determine links between colonies, marine & forest habitats • Habitat Assessment: —Micro-scale within subcolony —Micro-scale in colony, foraging hot spots —Macro-scale coastal surveys, gap analysis	• Forestry/marine environment linkage: possible sedimentation effects on kelp & feeding habitat of sea otters, gray whales, other species		
Predictive Modeling	2. Conceptual model of sanctuary ecosystem: input, output, stresses 4. Model nearshore geomorphology & physical & biological links				Physical modeling	
Methodology	Emphasize statistical reliability	Determine or develop assessment methods for shellfish species. Aquaculture has limited role in Sanctuary research needs now. • Possible need for kelp aquaculture (e.g., *Macrocystis*). • Need for additional spawning habitat may foster aquaculture. 7. Involve ALL constituents, including assistance, education.	Define goals to design methodology & establish statistical power for timely & fiscally pragmatic studies. Monitor population trends with statistical rigor (esp. for wintering, non-breeding species & murrelets). Can we improve efficiency & reduce costs by applying results of studies in other similar systems?	Develop protocols to build a tissue archive for contaminants including biotoxins. Tribal harvest could enable studies of mammal tissues and collection of other biological specimens.	Moorings (inshore buoys with 30 m depth resolution) at Focus Area C sites: —cost-effective & comprehensive —but has no depth resolution & spatially confined	Opportunities for collaborative research efforts and standardizing protocols. Plan for future research to increase coordination and efficiency.

*Numbers (where present) indicate priority assigned research category. Lack of number indicates no priorities assigned.

Table 4 (continued). Recommended Research

Type of Research	Intertidal, Subtidal, Estuarine, Kelp & Seagrass Ecology*	Nearshore Fish, Shellfish & Aquaculture*	Seabirds	Marine Mammals	Oceanography, Geology, Biotoxins, Contaminants	Historic & Pre-historic Uses, Archaeology
Method-ology (cont.)			Methodological Questions: • How to define populations (political vs. biological, e.g. the Washington or Puget Sound population in a particular season). —genetic populations vs spatial distributions —implications for monitoring, research, & management —mechanisms include morphometrics, gen-etic [e.g., DNA], tele-metry, at-sea surveys of colony dispersal • Variables affecting censusing & monitoring: —time of day; tide; distance from shore; shoreline type; water depth, salinity & temperature • how do we deal with air-boat comparisons? —plane surveys give broad overview but lack accuracy & environmental correlation —boat surveys give a narrower view but do allow environmental correlations			

*Numbers (where present) indicate priority assigned research category. Lack of number indicates no priorities assigned.

Table 5. Data Needs Interactions Between Groups

Group Needing Data \ Group Data Needed From	Intertidal, Subtidal, Estuarine, Kelp & Seagrass Ecology	Nearshore Fish, Shellfish & Aquaculture	Seabirds	Marine Mammals	Oceanography, Geology, Biotoxins, Contaminants	Historic & Pre-historic Uses, Archaeology
Intertidal, Subtidal, Estuarine, Kelp & Seagrass Ecology		Synpotic survey of nearshore baitfish Map of smelt spawning area & habitat Monitor biotoxins in baitfish			Monitor biotoxins in baitfish Sediment dynamics & nearshore physics Water quality problems	Tribal knowledge & archaeological evidence of distribution & abundance of smelt and other species
Nearshore Fish, Shellfish & Aquaculture						
Seabirds					Identify oceanographic causes of hot-spots Choice of observation site & platform	
Marine Mammals	Nearshore studies, benthic community, kelp				Biological & physical oceanography studies	Studies integrating archaeology could provide important information
Oceanography, Geology, Biotoxins, Contaminants			Use birds as bioindicators			
Historic & Pre-historic Uses, Archaeology					Correlate shipwreck locations with oceanographic data to improve predictability	

Table 6. Oceanographic Research Needs for Selected Management Issues

(Oceanography, Coastal Geology, Biotoxin & Contamination Focus Group)

Management Issue	Category of Research Needed					
	Aerial Surveys	Seafloor & Sediment Mapping	Biotoxins	Water Quality	Oceanography & Circulation	Contaminants
Oil Spills	■	■			■	■
Biotoxins			■		■	
Habitat Loss & Alteration	■	■			■	■
Natural Resource & Biodiversity Decline	■		■	■	■	
Harvestable Resource Decline		■	■			■
Coastal Erosion	■	■			■	
Contaminant Loading		■			■	■
Long-Term Environmental & Climate Change				■	■	
Exotic Species Invasion	■		■		■	
Establishment & Availability of Baseline Data	■	■	■	■	■	■
Establish Threshold Values	■	■	■	■	■	■

(shading indicates designated management issue requires data from shaded research category)

Appendices

Appendix 1

Research Mandate of the Olympic Coast National Marine Sanctuary

Reprinted from: NOAA. 1993. Olympic Coast National Marine Sanctuary. Final environmental impact statement/management plan. Vol. I, Sec. III: Research. U.S. Department of Commerce, Washington, D.C.

Section III: Research

III.A. Introduction

Effective management of the Olympic Coast National Marine Sanctuary requires the development of a coordinated and focused research program. Research conducted within marine sanctuaries is designed to improve knowledge of the sanctuary's environment and resources and provide data and information that is most useful to the sanctuary manager and decision-makers. The research conducted within sanctuaries contributes to the general body of scientific knowledge, and the management-specific focus of the research provides useful information for application in other marine and coastal areas. Sanctuary researchers, managers and education directors should coordinate their efforts to ensure a strong link between management/education needs and research projects. The research agenda should also be coordinated with the research agendas of the other marine sanctuaries on the West Coast to maximize the benefits of research results.

Research conducted within the sanctuary will focus specifically on those management issues that relate to the protection of significant sanctuary resources. The highest priority for research is generation of a "site profile" which will form the foundation for the contingency plan, regulatory regime, and education and research programs on natural resource abundance, characteristics, and processes for the area. Past resource data will be utilized as well as ongoing monitoring and research results. The monitoring program should be both species-specific as well as examine questions involving communities and the entire local ecosystem. Management-directed research will address practical, use-oriented or "cause-and effect" studies. Long-term monitoring

and the resultant data base will provide the foundation for interpreting or predicting natural or human-induced events in the sanctuary and adjacent areas. General directions and priorities for additional research are provided in this section as a guide for identifying and selecting future appropriate research projects.

The sanctuary will work cooperatively with other institutions whenever possible in conducting research. Federal, tribal, state, and local agencies, and universities in Washington State, have important capabilities that could aid in meeting sanctuary objectives. In particular, the Washington legislature established a new Olympic Natural Resources Center, to be located on the western side of the Olympic Peninsula, to conduct research and education in forestry and ocean management. This new Center, a unit of the University of Washington, would be an ideal partner to work with sanctuary staff on ocean issues and educational programs.

III.B. Goals

The purpose of Sanctuary research activities is to improve understanding of the resources and characteristics of the marine environment off the Olympic Peninsula to resolve specific management problems, and to coordinate and facilitate information flow between the various research institutions, agencies and organizations. A major emphasis of the research program will be to encourage studies that investigate the natural processes at the land-sea interface. Research results will be used in education programs for visitors and others interested in the Sanctuary, as well as for resource protection. The strategies to be employed in the research program are to:

- Establish a framework and procedures for administering research to ensure that research projects are responsive to management concerns and that results contribute to improved management of the Sanctuary;
- Incorporate research results into the interpretive/education program in a format useful for the general public;
- Focus and coordinate data collection efforts on the physical, chemical, geological and biological oceanography of the Sanctuary;
- Encourage research that examines biodiversity within the habitats of the Sanctuary;
- Encourage studies that integrate nearshore and open ocean research findings for a more complete understanding of processes affecting both zones;

- Initiate a monitoring program to assess environmental changes as they occur due to natural and human processes;
- Identify the range of effects on the environment that would result from predicted changes in human activity or natural phenomena;
- Assure that research activities do not harm or diminish Sanctuary resources;
- Encourage information exchange among all the organizations and agencies undertaking management-related research in the Sanctuary to promote more informed management;
- Evaluate the effectiveness and efficiency of the research program and its integration with resource protection and education objectives.

III.C. Framework for Research

Research projects will be directed to three basic management questions.

- Baseline studies to determine the features and processes of the natural environment; the abundance, distribution, and interaction of the living resources; and the distribution and status of historical resources and the pattern of human activity in the Sanctuary from prehistoric times to the future.
- Monitoring to document changes in environmental quality, in ecology, and in human activity.
- Predictive studies to assess the causes and effects of environmental and ecological changes.

Each of these categories is described in more detail below.

III.C.1. Baseline Studies

Baseline studies will be designed to obtain a better understanding of the physical oceanography and ecology of the Sanctuary. They generally refer to studies of abundance, distribution, and movement of species, and selected chemical, physical, and geological parameters. In the area of the proposed Olympic Coast sanctuary, the basic characteristics of many important species populations and habitats are not known. However, there is an indication that there has been a loss of habitat and species in recent years. Inventories of selected species, particularly threatened or vulnerable species within these populations, represent an important direction for research. Some baseline studies will focus on the inventory and description of sanctuary habitats. Over the long

term, there may be a need for a detailed inventory of the intertidal and subtidal habitats of the sanctuary that build on previously conducted surveys, and personal observations.

Since there are barges and vessels carrying hazardous substances through and near the Sanctuary, the Sanctuary manager will need sound information on water circulation. This information would be used to improve understanding of the dispersion pattern of possible oil spills and land-source and ocean-source discharges in the waters within or adjacent to the Sanctuary, and as part of the Sanctuary's contingency planning efforts.

Basic physical oceanographic studies should focus on local circulation patterns offshore and in the Strait of Juan de Fuca, upwelling processes, and the interchange of water masses such as the Columbia River Plume and more saline open ocean water masses. To accomplish this goal of understanding regional circulation, the Sanctuary could assist with the development and dissemination of information from existing monitoring stations such as NOAA tide gauges, current meters, thermistor chains and satellites (i.e., the NOAA polar orbiting satellites with Advanced Very High Resolution Radiometer instruments that can image sea surface temperature). Process-oriented studies can use resident, indicator species to identify local water mass movement and to elucidate key productivity areas or areas of high diversity. Results can then be incorporated into an understanding of food web relationships and predator-prey foraging dynamics.

Comprehensive knowledge of the distribution of organisms and their dependence on environmental factors is needed for interpretation as well as for resource protection. At representative depths and locations, the environment should be characterized by the collection of additional baseline data on water temperature and salinity, light penetration, upwelling circulation and nutrient loading. This information should be correlated with data on the abundance and distribution, by depth zone and location, of species populations living within and transiting the Sanctuary. Data of this type have been collected at particular points along the shoreline by the numerous research institutions in Washington State, but due to the remoteness of the area and limited access points, there are many gaps in our knowledge of the marine ecology off the Olympic Peninsula, particularly land-sea interactions.

The interaction of physical oceanography with biological studies will assist in developing an understanding of the ecology of the region and the general health and

productivity of the Sanctuary. The research and education programs in general will emphasize a multi-disciplinary approach to basic and applied scientific issues. The geographic location of the proposed Sanctuary provides an excellent opportunity to integrate research on the effects that human uses in the watershed and in the marine environment have on marine resources. This data would be invaluable in estimating the effects, if any, of present and future land-use practices on the marine environment.

Additionally, a historical context study, including a general literature search building on existing work, will be conducted to identify probable historical sites (including cultural, archeological, and paleontological sites) within the Sanctuary. This research will be followed by a field reconnaissance-type remote sensing survey and archeological assessment to locate and evaluate the extent to which historical resources are based in the Sanctuary. These baseline historical resource studies will provide the fundamental information necessary for developing a historical resource management strategy and education/interpretation program for the Sanctuary.

The recently developed Maritime History Museum will provide a new maritime museum in Seattle. Coordination with facilities adjacent to the Sanctuary and in larger population centers will enhance public awareness of Sanctuary efforts to protect and research important historical resources.

III.C.2. Monitoring

Effective management requires an understanding of long-term changes to the status of the resources and human uses affecting those resources. Monitoring activities provide for the planned systematic collection of data on selected parameters to detect trends in ecosystem populations, communities, habitats, and processes. A well-designed monitoring program can help detect natural cycles and trends, as well as unusual changes, and then relate them to one or more sources of probable disturbance. A monitoring program may help to distinguish between trends related to natural and human-induced activities. Over the long term, a monitoring program should indicate the health of the sanctuary ecosystem and its important resources.

Marine resource monitoring programs can be costly and complex. For these reasons, the selection of parameters to monitor is an important scientific and management question. The Sanctuary Research Division (SRD) will continue to seek advice from and coordinate with other agencies and scientists who conduct marine monitoring, and

provide technical and other support where possible. Additional programs may also be initiated for important species or habitats of special concern not covered by existing programs. The research subcommittee of the Sanctuary Advisory Committee (SAC) will be instrumental in directing the monitoring program.

Overall, the monitoring program will assist in our understanding of the general health of the Olympic Coast and surrounding waters. The program could help discover sources of pollutants and assist in the establishment of cause and effect relationships as part of long-term toxicological evaluations. Monitoring could also elucidate any problems or changing patterns that had not been previously identified. Ultimately, the monitoring program will address the application of the findings to basic science as well as applied management purposes.

Sanctuary staff will also monitor vessel traffic in coordination with the U.S. Coast Guard to assess the needs of additional preventative strategies.

III.C.3. Analytical/Predictive Studies

In addition to baseline research and monitoring, the Sanctuary research program will continue studies, as needed, to analyze the causes and consequences of ecosystem changes and to predict their effects on new and more intense human activity in the area. Unlike the monitoring program, these predictive studies are envisioned to be more short-term and directly targeted to an immediate management issue. Studies could be made to determine the effects on marine mammals of possible increases in boating activity if heightened interest in whale watching and fishing excursions results from Sanctuary establishment. A knowledge of these effects would enable management to provide information to Sanctuary users to avoid disturbing these animals unnecessarily.

Other studies of whales, pinnipeds and seabirds in the Sanctuary could be initiated to determine their range, their migration patterns, and their dependence on the food resources of the Sanctuary. One such study, for example, might be an investigation to determine (a) whether the decrease in Steller sea lions can be attributed to a decline in prey availability, and to compare the results to a similar study on the relatively stable Steller sea lion population on Ano Nuevo Island, California; (b) the importance of the fish stocks in sustaining the Steller sea lion population; and (c) the interaction of fishing on pinniped, mammal, and seabird populations and vice-versa.

III.D. Selection and Management of Research Projects

Projects considered for funding by the SRD should be directed to the resolution of sanctuary management issues and concerns. The sanctuary manager, Sanctuary Advisory Committee, and SRD will follow procedures developed by SRD to ensure that each sanctuary's research program is consistent with the national program policies and directions. These procedures include preparing an annual Sanctuary Research Plan (SRP), and monitoring the progress of research in the sanctuary.

III.D.1. Preparing an Annual Operating Plan (AOP)

Each year the sanctuary manager will prepare a Sanctuary Research Plan (SRP) with support by the SAC. The AOP is a brief description of the goals for each fiscal year and a justification of how these goals fit into the guidelines of the approved management plan. SRD will then incorporate the SRP into a national plan that includes annual plans for each sanctuary. Steps involved in the annual planning process include:

- Identifying management concerns for the sanctuary with supporting evidence or rationales.

- The sanctuary manager, in cooperation with the SAC and SRD, establishes research priorities based on the identification of management concerns. The most important factors to be considered in establishing annual research priorities will be:

  (a) Immediate or evolving management issues that may be resolved through directed research projects;

  (b) The prospects of research already in progress; and

  (c) The availability of funds, equipment, and instruments for research support.

- Research workshops are held on an occasional basis to facilitate the identification of research problems. After the management issues and research priorities are developed, a draft SRP is prepared.

- An SRP is prepared that includes documentation of how each project meets the national selection criteria. The final SRP is then incorporated by the research coordinator at program headquarters into a National Sanctuary Research Plan. The highest ranking research projects are selected from the national plan and a procurement schedule is prepared.

- A research announcement and request for proposals (RFP) is prepared. The announcement discusses management concerns and summarizes past and on-

going research. Its purpose is to solicit proposals from the scientific community that satisfy the criteria specified in the SRP.

Occasionally, research proposals may include activities that are prohibited by sanctuary regulations (e.g., taking of marine mammals). In such cases, NOAA may review the proposal and issue a permit allowing the activity to proceed. The permit review process for research is outlined in Appendix ___. NOAA may also determine that all or part of the research should be conducted outside of sanctuary boundaries. Research focusing on protected or endangered species may require additional research permits from other agencies.

III.D.2. Monitoring Progress

The sanctuary manager will monitor the performance of research projects and keep records of ongoing research, equipment being used on site, frequency of researchers' visits, and project progress. In order to ensure conformance to schedules outlined under the terms of the research contract, the researchers must prepare progress reports and final reports for review by SRD and the sanctuary manager. Scientists and resource managers may review final reports before approval by SRD. Additionally, SRD will publish outstanding project reports in its Technical Report Series.

III.D.3. Information Exchange

Direct SRD funding for research is limited. To augment directly funded research, SRD will encourage other funding sources to support research that complements sanctuary management goals. In the process of soliciting research projects from other agencies and private institutions, SRD will make available current sanctuary resource data obtained from past and ongoing projects.

Appendix 2

Olympic Coast Marine Research Workshop Steering Committee

Steve Barry
Washington Department of Fish & Wildlife
48 Devonshire Rd.
Montesano, WA 98563
(360) 249-4628 voice, 249-5484 fax

Ed Bowlby
Olympic Coast National Marine Sanctuary
138 W. 1st St.
Port Angeles, WA 98362-2600
(360) 452-2153 voice, 457-8496 fax
ebowlby@ocean.nos.noaa.gov

C. Jeffrey Brandt
Battelle Seattle Research Center
4000 NE 41st Street
Seattle, WA 98105
(206) 528-3350 voice, 528 3552 fax
brandt@battelle.org
(previously at Battelle Marine Sciences Lab)

Paul Crawford
Natural Resources Management
Olympic National Park
600 East Park Avenue
Port Angeles, WA 98362
(360) 452-4501x284 voice

Denise Dailey
Makah Fisheries Management
P.O. Box 115
Neah Bay, WA 98357
(360) 645-2201x543 voice, 645-2323 fax

Jim Harp
Quinault Indian Nation
P.O. Box 189
Taholah, WA 98584
(360) 276-8211 voice, 276-4191 fax

Cat Hoffman
Chief, Natural Resources Management
Olympic National Park
600 East Park Ave.
Port Angeles WA 98362
(360) 452-0314 voice, 452-0335 fax
Cat_Hoffman@nps.gov

Jim Jorgenson
Fisheries Biologist, Hoh Tribe
HC-80, Box 917
Forks, WA 98331
(360) 374-6582 voice, 374-6549 fax

Thomas F. Mumford, Jr.
Washington Department of Natural Resources
Division of Aquatic Resources
P.O. Box 47027
Olympia, WA 98504-7027
(360) 902-1079 voice, 902-1786 fax
tmkk490@gwgate.wadnr.gov

John Pierce
Washington Department of Fish & Wildlife
600 Capitol Way N.
Olympia, WA 98501-1091
(360) 902-2511 voice, 902-2162 fax
piercdjp@dfw.wa.gov

Paul Ringgold
65 Linden Street
New Haven, CT 06511
(203) 777-2471 voice
pcring@minerva.cis.yale.edu
(previously with Olympic Natural Resources Center)

Anne Shaffer
Washington Department of Fish & Wildlife
P.O. Box 2263
Port Angeles, WA 98362
(360) 796-4601x224 voice, 796-4997 fax
SHAFFJA@mail.dfw.wa.gov
(previously with Quileute Natural Resources)

Eric Shott, Management/Habitat Biologist
Northwest Indian Fisheries Commission
Coastal Office
P.O. Box 1029
Forks, WA 98331
(360) 374-5501 voice, 374-5592 fax

Miranda Wecker
Olympic Natural Resources Center
P.O. Box 1628
Forks, WA 98331
(360) 374-3220 voice, 374-3220 fax
mwecker@u.washington.edu

Ulrich Wilson
Coastal Refuge Office
U.S. Fish & Wildlife Service
P.O. Box 450
Sequim, WA 98382
(360) 457-8792 voice, 457-9778 fax

Appendix 3

List of Workshop Participants

* denotes focus group facilitators

Shelly Ament
Washington Department of Fish & Wildlife
PO Box 1933
Sequim, WA 98382
(360) 681-4276 voice

Steve Barry
Washington Department of Fish & Wildlife
48 Devonshire Road
Montesano, WA 98563
(360) 249-4628 voice, 664-0689 fax

Paul Blake
Jefferson Elementary School
1336 Piedmont Rd.
Port Angeles, WA 98363
(360) 457-4231 voice, 457-4649 fax, 928-2150 home

Ed Bowlby
Olympic Coast National Marine Sanctuary
138 West First St.
Port Angeles, WA 98362
(360) 452-2153 voice, 457-8496 fax
ebowlby@ocean.nos.noaa.gov

Mary Sue Brancato
Parametrix, Inc.
5808 Lake Washington Blvd. NE
Kirkland, WA 98033-7350
(206) 822-8880 voice, 889-8808 fax

Tom Butler
441 Hudson Road
Port Angeles, WA 98363
(360) 928-0107 voice

Richard Chesmore
Archeologist, R.C. & A.
P.O. Box 1222
Forks, WA 98331
(360) 374-5453 voice

Dave Conca
Archeologist, Olympic National Park
600 E. Park Ave.
Port Angeles, WA 98362
(360) 452-4501 voice

Frank Cox
Biotoxin Coordinator, Wash. Dept. of Health
Shellfish Program, P.O. Box 47824
Olympia, WA 98504-7824
(360) 753-5994 voice, 586-4499 fax

Denise Dailey
Makah Fisheries
PO Box 115
Neah Bay, WA 98357
(360) 645-2167 voice, 645-2323 fax

*Megan Dethier
UW Friday Harbor Laboratories
620 University Rd.
Friday Harbor, WA 98250
(360) 378-2165, (360) 543-1273
megand@fhl.washington.edu
(206) 543-1484 voice, 543-1273 fax

George Galasso
Olympic Coast National Marine Sanctuary
138 West First St.
Port Angeles, WA 98362
(360) 457-6622 voice, 457-8496 fax
ocnms@ocean.nos.noaa.gov

*Pat Gearin
NOAA - National Marine Mammal Lab
7600 Sand Point Way NE
Seattle, WA 98115
(206) 526-4034 voice, 526-6615 fax

Guy Gelfenbaum
U.S. Geological Service
600 4th Street
St. Petersburg, FL 33701
(813) 893-3100x3017 voice, 893-3333 fax
ggelfenbaum@wayback.er.usgs.gov

Paul Gleeson
Olympic National Park, Cultural Resources
600 E. Park Avenue
Port Angeles, WA 98362
(360) 452-0316 voice, 452-0335 fax

Thomas Good
Dept. of Systematics & Ecology
University of Kansas
Lawrence, KS 66045
(913) 864-3325 voice
tomgood@falcon.cc.ukans.edu

Greg Green
Parametrix, Inc.
5808 Lake Washington Blvd. NE, Suite 200
Kirkland, WA 98033-7350
(206) 828-8880 voice, 889-8808 fax

*Barbara Hickey
School of Oceanography
Box 357940
University of Washington
Seattle, WA 98195-7940
(206) 543-4737 voice, 685-3354 fax

Cat Hoffman
Olympic National Park, Natural Resources
600 East Park Avenue
Port Angeles, WA 98362
(360) 452-0314 voice, 452-0335 fax
Cat_Hoffman@nps.gov

Roger Hoffman
Olympic National Park, Natural Resources Mgmt.
600 East Park Avenue
Port Angeles, WA 98362
(360) 452-4501x247 voice, 452-0335 fax
Roger_Hoffman@nps.gov

*Rita Horner
School of Oceanography
Box 357940
University of Washington,
Seattle, WA 98195-7940
(206) 543-8599 voice, 543-0275 fax
rita@ocean.washington.edu

Scott Horton
Washington Dept. of Natural Resources
411 Tillicum Lane
Forks, WA 98331

Todd Jacobs
Manager, Olympic Coast National Marine Sanctuary
138 West 1st Street
Port Angeles, WA 98362
(360) 457-6622 voice, 457-8496 fax

Steve Jeffries
Washington Dept. of Fish & Wildlife
Marine Mammal Investigations
7801 Phillips Drive SW
Tacoma, WA 98498
(206) 589-7235 voice, 589-7180 fax

Jim Jorgensen
Fisheries Manager
Hoh Tribe Fisheries
2464 Lower Hoh Road
Forks, WA 98331
(360) 374-6582 voice, 374-6549 fax

Bernard Krausse
National Biological Service
21261 Hoko-Ozette Road
Clallam Bay, WA 98326
(360) 963-2725 voice
OLYM_Ozette_Ranger_Station@nps.gov

Mitch LeSoing
Quileute Natural Resources Environmental Program
P.O. Box 187
La Push, WA 98350-0187
(360) 374-5695x35 voice, 374-2250 fax

Bob Lineback
Ranger, Olympic National Park
Mora Subdistrict Ranger Station
3283 Mora Road
Forks, WA 98331
(360) 374-5460 voice, 452-0348 fax

Anita McMillan
Washington Department of Fish & Wildlife
PO Box 1686
Port Angeles, WA 98362
(360) 457-4601 voice, 457-4601 fax

John Meyer
Olympic National Park, Natural Resources Division
600 East Park Avenue
Port Angeles, WA 98362
(360) 452-4501x246 voice

*Thomas Mumford, Jr.
Washington Department of Natural Resources
Division of Aquatic Resources
P.O. Box 47027
Olympia, WA 98504-7027
(360) 902-1079 voice, 902-1786 fax
tmkk490@wadnr.gov

*Jan Newton
Washington Department of Ecology
PO Box 47710
Olympia, WA 98504-7710
(360) 407-6675 voice, 407-6884 fax

Steve Osmek
NOAA Marine Mammal Lab
7600 Sand Point Way NE, Bldg. 4
Seattle, WA 98115
(206) 526-4034 voice, 526-6615 fax
osmek@afsc.noaa.gov

*Robert Paine
Department of Zoology
Box 351800
University of Washington
Seattle, WA 98195-1800
(206) 543-1649 voice, 543-3041 fax

*Julia Parrish
Department of Zoology
Box 351800
University of Washington
Seattle, WA 98195-1800
(206) 616-2958 voice, 543-3041 fax
jparrish@u.washington.edu

Dan Penttila
Washington Department of Fish & Wildlife
1702 Anderson Road # 4
Mt. Vernon, WA 98273
(360) 428-1011 voice, 428-1008 fax

Lisa Randlette
Environmental Planner
Washington Department of Natural Resources
Aquatic Lands Division
PO Box 47027
Olympia, WA 98504-7027
(360) 902-1085 voice, 902-1786 fax

Bill Rohde
Olympic National Park, District Ranger
18195 Upper Hoh Rd.
Forks, WA 98331
(360) 962-2283 voice

*Herb Sanborn
National Marine Fisheries Service
2725 Montlake Blvd.
Seattle, WA 98112-2013
(206) 553-7737 voice

Carl Schoch
Oregon State University
College of Ocean and Atmospheric Science
Corvallis, OR 97331
(541) 737-5229 voice, (541) 737-2064 fax
cschoch@oce.orst.edu

Pete Schroeder
Friends of the Marine Lab
620 W. Anderson Road
Sequim, WA 98382
(360) 683-7437 voice, 683-5428 fax

June Schumack
Quileute Natural Resources
P.O. Box 187
La Push, WA 98350

Anne Shaffer
Washington Department of Fish & Widlife
PO Box 2263
Port Angeles, WA 98362
(360) 796-4601x224 voice, 796-4997 fax

*Chris Sherwood
Batelle marine Sciences Lab
1529 West Sequim Bay Road
Sequim, WA 98382
(360) 681-3618 voice, 681-3699 fax
crs@constance.pnl.gov

Eric Shott
Northwest Indian Fisheries Commission
Coastal Office
P.O. Box 1029
Forks, WA 98331
(360) 374-5501 voice, 374-5592 fax
eshott@nwifc.wa.gov

*Doug Simons
Washington Department of Fish & Wildlife
48 Devonshire Road
Montesano, WA 98563
(360) 249-1204 voice, 664-0689 fax
simondds@dfw.wa.gov

Steve Speich
Dames & Moore
1790 East River Road, Suite E-300
Tucson, AZ 85749
(520) 529-1141 voice, 529-2449 fax
sspeich@azstarnet.com

*Lee Stilson
Washington Department of Natural Resources
PO Box 47027
Olympia, WA 98504-7027
(360) 902-1281 voice, 902-1786 fax
lssk490@wadrn.gov

Richard Strickland
School of Oceanography
Box 357940
University of Washington
Seattle, WA 98195-7940
(206) 543-3131 voice, 543-6073 fax
strix@ocean.washington.edu

Jean Takekawa
Deputy Refuge Manager
U.S. Fish and Wildlife Service Nisqually NWR Complex
100 Brown Farm Road
Olympia, WA 98516
(360) 753-9467 voice, 534-9302 fax
willard_b-hesselbart@fws.gov

Thomas Terich
Professor in Geography/Environmental Studies
Western Washington University, MS 9085
Bellingham, WA 98225
(360) 650-3284 voice, 650-7702 fax

*Ron Thom
Battelle Marine Sciences Lab
1529 W. Sequim Bay Road
Sequim, WA 98382
(360) 681-3657 voice, 681-3681 fax
rm_thom@ccmail.pnl.gov

Chris Thompson
Wa. Dept. of Fish & Wildlife
Department of Zoology
Box 351800
University of Washington
Seattle, WA 98195
(206) 210-0155 voice, 543-3041 fax

Dan Tracy
Seawalker
14015 41st Avenue NE
Seattle, WA 98125
(206) 361-2742 voice
dtracy@wrc.noaa.gov

Barry Troutman
Washington Department of Fish & Wildlife,
Spill Response Team
600 Capitol Way North
Olympia, WA 98501-1091
(360) 902-2621 voice, 902-2938 fax

Glenn VanBlaricom
Washington Cooperative Fish & Wildlife
Research Unit, School of Fisheries
Box 357980
University of Washington
Seattle, WA 98195-7980
(206) 543-6475 voice, 685-7471 fax
glennvg@fish.washington.edu

Kenneth L. Warheit
Washington Department of Fish & Wildlife,
Spill Response Team
600 Capitol Way North
Olympia, WA 98501-1091
(360) 902-2595 voice, 902-2938 fax
warheit@u.washington.edu

Miranda Wecker
Olympic Natural Resources Center
PO Box 1628
Forks, WA 98331
(360) 374-3220 voice, 374-3336 fax, (360) 875-6609 home
mwecker@u.washington.edu

Kitty Weisman
Washington Department of Ecology
PO Box 47600
Olympia, WA 98504-7600
(360) 407-7560 voice

*John C. Wekell
NOAA/NMFS Utilization & Research
2725 Montlake Blvd. E
Seattle, WA 98112-2097
(206) 860-3388 voice, 860-3394 fax

Mary Williams
Hoh Tribe
2464 Lower Hoh Road
Forks, WA 98331
(360) 374-6582 voice, 374-6549 fax

Jacilee Wray
Olympic National Park
600 E. Park Ave.
Port Angeles, WA 98362
(360) 452-4501x292 voice, 452-0337 fax
Jacilee_Wray@nps.gov

John Wullschleger
Olympic National Park
196283 Highway 101
Forks, WA 98331
(360) 374-1222 voice, 374-1250 fax
john_wullschleger@nps.gov

Appendix 4

Marine Resource Management Priorities

Miranda Wecker, ONRC Marine Program Manager

One of the stated goals of this workshop is to begin to determine whether the research community is satisfactorily addressing the key management issues facing managers and users of Olympic Peninsula marine resources. The workshop steering committee decided that a brief outline of priority management issues should be presented in the beginning of the plenary program. Later, throughout the workshop, participants can compare the status and direction of research to this list of key public concerns. The steering committee emphasized that the presentation of management concerns should not lead into a discussion of the pros and cons of particular policies themselves. Rather, the purpose of this presentation is merely to establish a way to evaluate whether science is directly engaged in addressing social concerns.

One of the most complete and recent reports that identifies management problems is the proceedings of a two-day workshop in 1993 sponsored by the Olympic Natural Resources Center (ONRC) held at Grays Harbor College in Aberdeen, Washington (ONRC 1994). That workshop was organized to bring together the widest possible range of viewpoints so that the University of Washington would be better able to define the role of ONRC's marine program.

The Washington State Legislature created ONRC in 1989 and mandated that it would be jointly administered by the College of Forest Resources and the College of Ocean and Fisheries Sciences within the University of Washington. The Legislature envisioned that ONRC would meet the pressing need for objective and credible information to define better ways to manage uses of the forests and the sea. ONRC would help citizens of the state define policies that, at once, allow commodity production and protect key ecological values. To take the most comprehensive approach to its mandate, ONRC was also instructed to explore the interrelationships and inter-connections between marine and terrestrial systems. The information gathered during the 1993 workshop in Aberdeen was considered in combination with the advice of more than 100 resource users and managers during the past several months, as ONRC has undertaken an

effort to select its near-term program priorities. In this presentation I will briefly run through that list of concerns and the programmatic agenda that has emerged.

The Human Context for Resource Issues

To begin identifying management challenges, it was felt important that ONRC consider the human context for resource management. Socio-economic trends set the stage for pressures on natural resources and thus in part define the relative urgency of management issues. To gain a sense of the human context, ONRC reviewed a recent report on demographic trends in Olympic Peninsula counties prepared by Dr. Annabelle Cook of WSU's Department of Rural Sociology. The report drew together data from U.S. Census reports for 1980 and 1990 on conditions in Clallam, Jefferson, Grays Harbor, Pacific, and Mason Counties. In addition to comparing conditions in each of the Olympic counties, they were all compared with the figures from the state as a whole.

Cook's data show that population growth has taken place at varying rates in the counties of the region. The counties that extend eastward towards the Seattle metropolitan area (Mason, Jefferson and Clallam Counties) have experienced more population growth than the two purely coastal counties: Pacific and Grays Harbor Counties. The performance of the economies of Olympic counties ranged from poor to dismal. While state median income levels rose slightly, Mason and Jefferson Counties saw a decline of somewhat less than $1,000. The decline was more marked in Clallam County where the median income decreased by over $2,000. In the southwestern coastal counties, the declines were even worse: median incomes dropped by almost $6,000 in Grays Harbor and slid almost $4,000 in Pacific County.

The poverty rate within the overall population increased noticeably in most Olympic counties, while it increased only slightly in the state as a whole. In keeping with a trend observed throughout the nation, poverty among children climbed in Washington State as a whole from just over 11% to nearly 15%. The rate of poverty among children began the decade near state levels in all Olympic counties except Jefferson County, where it was over 17%. By 1990, the rate had grown far worse in all Olympic counties. In Pacific County, one in four children lives in poverty. In Grays Harbor, Jefferson, and Mason Counties, one out of every five children lives in poverty. In Clallam County, 16% of the children are classified as poor. Poverty rates among the elderly declined at the state level, and dropped significantly in most Olympic counties, except in Grays Harbor and Pacific Counties, where it remained constant.

Educational attainment has been shown to be one of the most reliable predictors of economic success throughout life. It also has been correlated to environmental awareness and commitment to ecological precepts. Drop-out rates declined in the state as a whole, but increased in all but two (Jefferson and Mason) Olympic counties. In every county, the drop-out rate exceeds state levels. The percentage of adults having a four-year college education was substantially below state levels in all Olympic counties except Jefferson. During the decade studied, the percentage of adults with college education fell further behind as state levels increased. In Grays Harbor and Pacific Counties, the gap is most pronounced: only about 12 to 15% of the adult population has completed four or more years of education, in contrast to the state level of 23%.

The overall picture provided by the study indicates a region that has numerous challenges in the new era of increasing competition for jobs and businesses, in which education levels will be one of the leading indicators of community success. The data for the region show a greater dependence on natural resource extraction than seen for the state as a whole. It is this high level of dependence that has given rise to much of the intensity of the resource management debates.

Marine Resource Issues

The participants in Aberdeen workshop were not all of one mind regarding the definition or ranking of resource problems. Furthermore, the participant list shows that the meeting was probably more reflective of the perspectives of natural resource professionals, many of whom came from outside the Olympic region to attend the meeting. This section summarizes the management issues they ranked as important. Much of the discussion during the Aberdeen meeting was directed at general concepts such as "sustainability" and at procedural issues such as coordination and participation. Management needs articulated in such general terms are difficult to compare with the specificity of current scientific efforts that will be catalogued during the course of this workshop.

Workshop #1: An Ecosystem Approach to Understanding Coastal Resources

The first workshop saw an array of difficulties associated with "an ecosystem approach to management," including differences of values and views, scientific uncertainties, and the awkwardness and political pitfalls of multi-disciplinary and multi-agency coordination. Yet most participants appeared to believe that holistic integrated

approaches would be superior to those based on the narrow disciplinary analyses of the past. The concept of ecosystem management remains ill-defined and lacking in objective grounding. Some thought that by trying "ecosystem management," it would be brought into better focus (an adaptive management approach). Others worried that if integrated thinking cannot be done very well, then managers will base their risk judgments primarily on values and call that "ecosystem management." In the face of this lack of consensus, the group agreed on the need for more process, more coordination, more partnerships, more education, more research, and less conflict. The group also stated that while managers developed better management tools, areas of key ecological importance should be protected.

Needs:

- entity to facilitate partnerships.
- honest dialogue over ecosystem management
- reduce scientific uncertainty
- identify key ecological resources
- objective ecological information
- policies that are not excessively risk-averse
- protect the most important resources as we learn more

Workshop #2: Social and Cultural Impacts of Coastal Resource Management Decisions

This workshop explored a full range of socio-political, economic, and cultural perspectives that affect Olympic Peninsula resource management policies. Support was expressed again and again for the principles of local control and local empowerment through education and infrastructure improvement. Much of the discussion centered on the social stresses to Olympic communities brought about by economic transition in natural resource-based industries. The group called for greater efforts to bridge the socio-cultural differences that have contributed to heightened tensions and distrust.

Needs:

- opportunities for reciprocal education
- more comprehensive participatory processes
- balanced information exchange
- more objectivity and fair-mindedness
- social and cultural bridge-building involving respect

Workshop #3: Stresses to the Coastal, Marine and Estuarine Environments

The third group was asked to create a list of the current conditions and trends relevant to stresses on the coastal, marine and estuarine environments of the Olympic Region. The group referred to the following: oil spills, chemical contaminants, population growth, recreational uses, marine toxins, fecal contamination, El Niño, sediments, *Spartina*, exotics in ballast water, wildlife and fish habitat loss, declines in fish and seabird populations. The group discussed methodologies for ranking habitats in accordance with their importance. Furthermore, group members agreed that within systems, certain functions or components may be more essential than others. They ventured that it may be possible to predict when an irreversible threshold of ecological change would be crossed.

All these notions are relevant to the process of prioritizing issues and deploying resources strategically. According to the group, "litany of lacks" stands in the way of strategic thinking including: lack of coordination, lack of monitoring, lack of understanding, and lack of cooperation. The remedy proposed involved a more coordinated research agenda that could pull together and make better use of the efforts of existing agencies and institutions. Specific stressors were discussed more fully and the research and education needs alluded to, including the need for better baseline data on a wide range of species.

Needs:

- Threshold determinations (irreversibility) regarding stressors
- declining species
- water quality
- contaminants
- habitat loss and alteration
- exotics
- prioritization of habitats
- more baseline monitoring
- more coordination and cooperation

Workshop #4: Coastal Economic Development

The fourth workshop focused on economic development challenges and opportunities. It recognized that many factors influence the prospects for economic growth: the type of infrastructures available, the level of training of the local work force,

transportation options, and the proximity of resources. The competitive advantages of various parts of the Olympic region differ greatly, shaping the potential for and direction of economic development. The clear emphasis fell on educational opportunities in connection with the development of human resources. Opportunities for marine-based economic development were explored. The record indicates an emphasis on potential economic growth spurred by new marine recreation and eco-tourism opportunities. The extractive industries were also mentioned.

Needs:

- A peninsula-wide information center
- A catalyst for inter-jurisdictional cooperation
- Economic impact research
- Identification of marine-based business opportunities
- Facilitation for definition of sustainable development

Workshop #5: Aquaculture and Fisheries Enhancement

The fifth workshop produced a list of critical issues and concerns facing aquaculture and fisheries enhancement interests, among them water quality, habitat loss, population pressures, species declines, ocean influences, and the inadequacies of management regimes. The group also produced a list of specific research opportunities, including preparation of better predictive models for ocean productivity, diagnosis of shellfish diseases and biotoxin outbreaks, understanding of the impacts of exotic species, and development of baseline data on resources and processes. Also considered important were studies on artificial enhancement and its genetic impacts, and techniques to restore habitat and re-populate restored habitat. The group also wrestled with issues related to the management of resources and strategies to improve coordination and cooperation.

Needs:

- research into topics noted above
- better predictive models for ocean productivity, shellfish diseases, and biotoxin outbreaks
- understanding the impacts of exotic species
- baseline data on resources and processes
- studies on artificial enhancement and its genetic impacts
- techniques to restore habitat and re-populate restored habitat
- entity to translate research into usable products

- support consensus building among diverse people
- depository for all data and clearinghouse for information delivery

Significant Management Issues

After a brief review of Washington coast's primary marine resources and uses, this section describes the list of significant management issues identified by ONRC. The major utilized marine resources fall in three categories: salmonids, marine fish, and shellfish. Other uses of the marine environment include waste disposal, tourism, transportation, defense and residential uses. The following may be regarded as a "laundry list" of issues having varying degrees of urgency.

Salmonid issues

- Declines in wild / naturally spawning stocks (threat of ESA listing)
- Controversy over impacts of hatcheries
- Habitat loss
- Watershed alterations
- Fishing pressure
- Sports vs. commercial allocations
- Impacts of research

Crab Resource Issues

- Critical habitat degradation
- Biotoxins (domoic acid)
- Tribal co-management concerns
- Micro-management in the offing

Oyster Issues

- *Spartina* alteration of Willapa Bay and other coastal estuaries
- Burrowing shrimp alteration of oyster beds
- Contamination of beds by terrestrial uses
- Septic system failures and sewer treatment plants
- Pulp mill discharges of fecal coliform counts
- Biotoxins
- Productivity and condition
- Water quality & product assurance

Razor Clam Issues

- NIX and stock management

- Biotoxins
- Research in life history enhancement
- Education & compliance co-management

Groundfish Issues

- Rockfish overfished
- Closure of commercial catch in state waters
- Reduction of sports bag limit
- Uncertainty over effects of groundfish harvest on other sea life and seabirds
- Tribal concern over harvest level offshore North Coast

Residential & Tourism Issues

- Biotoxins
- Waste discharges
- Septic/sewer system failures
- Run-off from terrestrial activities
- "Natural" or altered levels of sediments and nutrients
- Estuarine waters most vulnerable

Marine Processes

- Coastal sediment transport
- Biological productivity
- Tsunami prediction
- El Niño prediction

Specific Marine-Terrestrial Interactions

- Pulp mill discharges & oyster bed closure
- Integration models
- Seabirds (marbled murrelet)
- Anadromous fish
- Estuarine model of watershed analysis

Conclusion

The problems are numerous, while the human and financial resources are limited. Near-term priorities had to be selected from this daunting list of issues. The priorities for ONRC's next several years of operation include: understanding estuarine resources and systems, exploring marine-terrestrial interactions, shellfish enhancement research, and building partnerships with Grays Harbor and Peninsula Colleges.

Appendix 5

Prehistoric and Historic Uses and Marine Archaeology of the Olympic Coast

Lee Stilson, Washington Department of Natural Resources

Editor's Note: The following material was presented as part of the results of the discussions of the Prehistoric and Historic Uses and Marine Archaeology focus group. This material would have been appropriate for a disciplinary address during the plenary session. However, because it was not presented during that session, it has been included as an appendix.

It is important to recognize and question the past uses of and demands and stresses on the marine environment as well as current and future uses. It is vital to recognize the difference between humans living as co-predators as part of the natural system and humans exploiting the natural system for commercial extractive purposes.

We need to understand cultural waterscapes. There was a prehistoric and historic orientation to the water. This had important implications in cultural dynamics, subsistence economies, and property ownership issues. We need to understand how people see and relate to their environment. What Sanctuary resources were utilized in the past? What resources are currently being utilized? We need an inventory and assessment of how local communities depend on coastal resources.

Humans probably have occupied this area for 12,000 years. Sites on the British Columbia Coast show marine adaptation for almost 10,000 years. Sites on the Oregon Coast show marine adaptation for 8-9,000 years. Yet the oldest site on the outer Washington Coast is Waatch (45CA1) at 3,800 years. This discrepancy almost certainly arises from the covering of older marine-oriented sites along the shoreline by post-Pleistocene sea level rise.

Archaeological work on the outer Washington Coast began in 1917 when Albert Reagan, a schoolmaster at La Push, excavated several shell middens between the Hoh River and Cape Flattery (Reagan 1917). Thirty years later, in 1947, Richard Daugherty surveyed the entire Washington Coast (Daugherty 1948). In 1948, Robert Hudziack and

Clarence Smith, using ethnographic and ethnohistoric evidence, located and tested 16 sites on the coast and just inside the Columbia River's mouth. In 1955, Bruce Stallard and Clayton Denman resurveyed the Olympic coastal strip between the Ozette and Queets Rivers (Stallard and Denman 1956). Much of this area was occupied by the Quileute and Hoh tribes.

Since 1956, 13 of the 90 sites reported from the outer Washington coast have been subjected to significant levels of excavation and have been reported or, at least, have radiocarbon dates available. These are listed below.

- Tatoosh 45CA207 (Friedman 1976)
- Archawat 45CA206 (Friedman 1976)
- Sooes 45CA25 (Friedman 1976)
- Waatch 45CA1 (Whitlam n.d.)
- Ozette 45CA24 (Gleeson 1980)
- Cannonball Island 45CA28 (Whitlam n.d.)
- White Rock Village 45CA30 (Guinn 1963)
- Sand Point 45CA201(Wessen 1983)
- La Push 45CA23 (Duncan 1981, Wessen 1977)
- Toleak Point 45JE9 (Newman 1959)
- Martin 45PC7 (Kidd 1967, Shaw 1977, Brown 1977)
- Minard 45GH15 (Roll 1974)
- Fishing Rocks 45PC35 (Minor 1983).

Radiocarbon dates are available for 12 of the 13 sites. The oldest known site on the outer coast is at Waatch, with a date of 3,810 B.P. (Whitlam n.d.). The radiocarbon dates from all other sites are less than 2,500 years, and all sites except Sand Point and Martin have historic components. The vast majority of archaeological data on the outer coast comes from the Ozette archaeological site. Assemblages and economic orientation to the marine and intertidal environments shows a great stability and continuity from late prehistoric to early historic times.

Wessen divided the coast into northern and southern sections (Point Grenville being the dividing line) based on the location of major habitation sites. In the north, habitation sites are mainly on the exposed outer coast, on stabilized beaches, first terraces, and major nearshore islands. Large communities were located at major river mouths and in areas that provided sheltered waters or easier access to resources (Wessen 1983). Easily defended positions were also favored habitation sites.

Many speakers at this workshop have mentioned the need for baseline data. Currently known archaeological sites can offer data sets spanning at least 3,800 years. These datasets can be very extensive. The faunal remains from the Ozette site numbers more than one million specimens. The floral and faunal data from archaeological sites can offer evidence of environmental change. In the southwest U.S., for example, packrat middens are used as an environmental indicator. As an example closer to home, a change from rock beach to silt/mud shellfish species at a site in Skagit County was attributed to environmental change related to Skagit delta progradation.

Archaeological data can be used to determine pre-existing conditions and natural environmental trends. Many different types of information may be available, such as faunal presence and absence and relative availability, biotoxins (mercury has been studied in tuna from Peruvian sites), and temperature change (O_3 concentration in shellfish varies with temperature).

All of this historic, prehistoric, and oral history information can be used to help reduce scientific uncertainty. A recent example is the use of archaeological and historical information to assess the probability of the existence of mountain goats in the Olympic Mountains before their recent introduction.

Appendix 6

Poster Session Abstracts

Razor Clam Population Assessment Pumped Area Methodology

Dan L. Ayres and Doug Simons, Washington Department of Fish and Wildlife

The Washington Department of Fish and Wildlife has been estimating populations of the Pacific razor clam (*Siliqua patula* Dixon) for more than 50 years using a mark-recapture method. This method produced adequate populations indices that were comparable for year-to-year comparisons, but did not accurately assess the entire population. Recent court decisions mandated co-management of all shellfish species with various Native American tribes. This brought the need for more accurate populations assessments. A new population assessment methodology, the Pumped Area Method, is being tested to see whether it will provide more accurate information and whether it is logistically feasible in the open coastal surf zone environment in which razor clams thrive.

The method uses a small cart-mounted water pump to liquefy the sand in 0.5 m^2 sample areas. All clams within these areas float to the surface and are counted and measured. The sampling areas are from randomly set perpendicular transects that cover the width of the clam beds from approximately the +3-foot level to the surf line, not to exceed 600 feet. The transects are then divided into 50 sections, and six plots are sampled at each section.

The three main objectives are 1) to determine the size distribution and numbers at length of the razor clam population on a given beach; 2) to estimate the mean density of clams by elevation on a given beach; and 3) to estimate the number of recruits (>3") and pre-recruits (< 3") on a given beach from the upper intertidal extent of a clam bed to seaward for 600 feet. A definite advantage in sampling juvenile clams using the pumped area method is shown over sampling with mark-recapture.

Olympic Coast National Marine Sanctuary Research Program

Ed Bowlby, George Galasso, and Todd Jacobs, Olympic Coast National Marine Sanctuary

Olympic Coast National Marine Sanctuary (OCNMS), dedicated in July 1994, encompasses some 2,600 square nautical miles of ocean waters, submerged lands, and intertidal habitat adjacent to the northern Washington coast. The offshore boundary generally follows the 100-fathom isobath. OCNMS research plans include identifying research priorities, supporting baseline data research and monitoring efforts, coordinating research activities with other organizations, producing publications, initiating workshops, and providing information for management decisions. The Sanctuary provides support to the research community with the following: in-kind support of staff and access to OCNMS's 36-foot R/V *Tatoosh* and to the 175-foot NOAA ship *McArthur*; assistance and coordination with other agencies, institutions, and tribes; and limited financial support.

Side-Scan Sonar Images from the Olympic Coast National Marine Sanctuary

Paul J. Farley, Battelle Marine Sciences Laboratory

In August, 1995, Battelle conducted a reconnaissance bottom survey of nearshore regions near Cape Flattery and Cape Alava. Side-scan sonar and a magnetometer were towed behind Tatoosh Island, and digital images of the bottom were recorded and logged using global-positioning system (GPS) navigation. The sonar images provide graphic views of a bottom habitat that consists of rocky outcrops amid coarse sediments. Images displayed at the workshop included targets of archaeological interest, such as possible fields of sunken debris near Tatoosh Island and Cape Alava.

Breeding Ecology and Behavior in the Glaucous-Winged Gull – Western Gull Hybrid Complex

Tom Good and Julie Ellis, Department of Systematics and Ecology, University of Kansas

We investigated the ecology and behavior of breeding pairs in the Western Gull – Glaucous-winged Gull hybrid zone. We collected data on nest-site characteristics, nesting habitat, and diet at 320 active nests on four sand islands in Grays Harbor, Washington, from egg-laying to chick fledging in 1995. Breeding success was lower than any reported for Western or Glaucous-winged Gulls. Hatching and fledging success was greatest in reed habitat, where nest density was highest, where the extent and percent cover of natural screens was greatest, and where screens blocked the nearest neighbor. The most common prey item was the Dungeness crab, *Cancer magister*. The percent occurrence of fish in the diet of pairs with chicks increased after hatching, while the percent occurrence of fish in the diet of pairs without chicks did not. Extensive egg predation by gulls and eagles resulted in low hatching rates and was mitigated almost exclusively by nesting in dense vegetation. Nesting habitat selection and nest-site microhabitat variation among Western Gull pairs, Glaucous-winged Gull pairs, and hybrids greatly influences breeding success of these colonies and may function in maintaining this hybrid zone.

Harmful Diatoms in Western Washington Waters

Sara E. Hinds, Rita A. Horner, and James R. Postel, School of Oceanography, University of Washington

Domoic acid concentrations up to 160 µg g^{-1} wet weight of shellfish meat were reported in razor clams (*Siliqua patula* Dixon) living in sandy beaches on the Pacific coast of Washington and Oregon in October, 1991. Toxin levels remained above the regulatory closure level of 20 µg g^{-1} wet weight for at least seven months. Domoic acid was also found in the viscera of Dungeness crabs (*Cancer magister* Dana) with levels up to 90 µg g^{-1} wet weight. As a result, two important fisheries, one primarily recreational (clams) and the other primarily commercial (crab), were closed. The crab harvest reopened within a few weeks when it was learned that cleaning the crabs, i.e., removing the viscera before cooking, and changing the cooking water frequently rendered the crab meat safe for human consumption.

The razor clam harvest remained closed through the regularly scheduled spring season in 1992, but by mid-summer, domoic acid levels were generally well below the

closure level. However, the fall 1992 harvest was delayed for more than a month because of the highest levels of PSP ever reported for razor clams, >4,000 µg g^{-1}. The spring 1993 season opened on schedule in late March, but the area between Grays Harbor and Willapa Bay was closed after four days and remained closed for more than a month because of PSP. As of October 1993, record numbers of razor clams were available, and both PSP and domoic acid levels were low. The fall 1993 harvest was scheduled to open on three beaches on 13 October, but two areas remained closed because clams were small.

It is not known for sure, 4–1/2 years after the original domoic acid problem on the U.S. West Coast, what organism(s) produced the domoic acid in western Washington waters, although *Pseudo-nitzschia australis* Frenguellia, isolated from the nearshore Pacific Ocean near the mouth of the Columbia River, produced domoic acid in culture (C. Villac, personal communication). Furthermore, only razor clams and Dungeness crabs were affected; no commercially grown bivalve molluscs became toxic. However, bad press during the 1991 incident reached throughout the U.S. and led to consumer boycotts of Washington shellfish during the holiday season, a time of maximum sales, even though the products were safe.

A Flexible-Scale Coastal Classification System

Carl Schoch, College of Ocean and Atmospheric Science, Oregon State University

Quantifying the distribution, abundance, and diversity of nearshore organisms over large areas presents problems to scientists and resource managers constrained by time, personnel, and funding. For example, no method currently exists to statistically extrapolate biological transect data from small to large spatial scales. Ecological responses caused by interacting physical and biological processes operate across multiple scales of space and time. At large scales (100–1000 km, decades to centuries), physical processes may become more important in determining organism distributions. Climatic variations delineate global habitats near one end of the space/time continuum, while competition for space and food determines nearshore community structure at the opposite end. Delineating coastal habitats at intermediate spatial scales becomes a complex task, requiring multiple parameters at each increment through the space/time continuum.

The objective of this study was to develop a coastal classification system, spanning spatial scales from 10 meters to 1,000's of kilometers, and based on a suite of physical factors linked to causal processes associated with ecological responses in the

nearshore environment. Complex shorelines can be partitioned into relatively discrete horizontal and vertical polygons with generally homogeneous morphodynamic attributes. The attributes of each unit are described and quantified, allowing statistical calculations for parametric or spatial distribution modeling of nearshore habitats.

In 1994-1995, the 138-kilometer Cook Inlet shoreline of Lake Clark National Park was classified using this system. Queries of the GIS database show the total area, length, and width of each intertidal habitat type, to a minimum resolution of 10 meters horizontally, as defined by alongshore polygon attributes such as wave runup, substrate character, slope angle and aspect. The methods developed in this study are applicable to oil spill damage assessments, inventory and monitoring programs, and global change studies in which economical or logistical constraints dictate a reliance on data collected from relatively localized areas, but when there is a need to extrapolate to broad spatial scales.

Archaeological Sites of the Northwest Washington Coast

Lee Stilson, Washington Department of Natural Resources, Aquatic Resources Division

Archaeological sites, including artifacts, features, and sites, can be divided into three categories based on how they came to be underwater:

1) those artifacts, features, or sites inadvertently placed or accidentally lost.

2) those items/features intentionally placed on tidelands and bedlands.

3) those upland archaeological sites inundated by eustatic changes, tectonic movement, or dam building, etc. This category would include almost the full range and variety of upland archaeological sites, both historic and prehistoric.

	LOST	INTENTIONALLY PLACED	INUNDATED
PREHISTORIC	Canoes, Anchors Net Weights, Fishing Weights and Hooks	Canoe Runs, Petroglyphs, Fish Traps/Weirs, Reef Nets, Trash Dumps	Villages, Campsites, Locations
HISTORIC	Ships, Aircraft, Locomotives, Collapsed Bridges, Anchors	Piers, Wharves, Docks, Bridge Abutments, Trash Dumps, Dams, Splash Dams, Boat Ramps, Landings, Placer Mines, Marine Railways	Forts, Homesteads, Towns, Waterfronts

Olympic National Marine Sanctuary Satellite Remote Sensing

Dan Tracy, SeaWalker Marine Services, Seattle, WA

Sea surface temperature and wind speed data are available, both in real-time and in historical archives, to anyone with a computer having access to the Internet. Sea surface temperature maps on the NOAA CoastWatch Program Home Page can be previewed easily and downloaded for further analysis. Clear satellite images are available 30 percent of the time during May–July, whereas August and September are generally overcast or foggy.

In addition, meteorological parameters including air temperature, barometric pressure, wind speed and direction, maximum hourly wind gust, period of wind gust, wave height, wind wave period, and dominant swell period are recorded by four stations in the Olympic Sanctuary: DESW1 (Destruction Island), TTIW1 (Tatoosh Island), NDBC 46041 (near Cape Elizabeth), and NDBC 4629 (near Willapa Bay).

Distribution and Abundance of Common Murres and Marbled Murrelets on the Outer Coast of Washington, with Comments on Sampling Methodology

Christopher W. Thompson, Monique Wilson, Kirsten Brennan, and William B. Barnett, Washington Department of Fish and Wildlife

The abundance and distribution of seabirds, especially threatened Marbled Murrelets, *Brachyramphus marmoratus*, and Common Murres, *Uria aalge*, on the outer coast of Washington is poorly known. In addition, methodologies for accurately counting specific seabird species at sea are rare, and those for Common Murres and Marbled Murrelets are poorly developed. To validate a methodology for counting these species at sea, it is necessary first to determine how their distribution and abundance is affected by biotic and abiotic environmental factors such as time of day, distance from shore, water depth, and prey abundance. From 31 July through 27 September, 1995, we conducted strip transects (200 meters wide) from boats 35 to 58 feet in length at different times of day (early and late morning, early and late afternoon) and different distances from shore (200, 400, 800, and 1200 meters) along the outer Strait of Juan de Fuca and outer coast of Washington.

Our results indicate that Marbled Murrelets and Common Murres are much more numerous along the northern outer coast and outer Strait of Juan de Fuca than along the southern outer coast, including Grays Harbor and Willapa Bay. This pattern of

abundance is correlated with the distribution of rocky versus sandy coastline and benthic substrate, and with the proximity to nesting areas (old growth forest and Tatoosh Island for Marbled Murrelets and Common Murres, respectively). We also document that, independent of distance from shore, Marbled Murrelets are most abundant early in the morning and decrease throughout the day, whereas Common Murres show no detectable change in abundance with time of day. Similarly, independent of time of day, Marbled Murrelets are most numerous close to shore (200 meters), and are rarely found beyond 1200 meters, whereas Common Murre abundance is not correlated with distance from shore between 200 and 1200 meters.

Washington Coastal Kelp Resources, Port Townsend to the Columbia River, Summer 1995

Robert van Wagenen, Ecoscan Resource Data, Freedom, CA

Along the Washington coast, there is an abundant "kelp" resource assemblage present (brown seaweeds, Order Laminariales), representing three families, 16 genera, and 26 species, more than any other area worldwide. Of these, the dominant, nearshore, surface canopy-forming species include *Nereocystis luetkeana* (bull kelp) and *Macrocystis integrifolia* (giant kelp). These species are present along 313 kilometers (12%) of the coast of Puget Sound, the Strait of Juan de Fuca, and the outer coast from Cape Flattery to Destruction Island. Each surface canopy, supported by air-filled pneumatocysts, is composed of individual plants that are attached to the bottom subtidal habitat by root-like "holdfasts." The vertical stipes, stretching from the sea floor to the surface canopy, provide critical habitat for numerous species of commercial and sport fish and hundreds of species of invertebrates, in addition to marine birds and mammals.

The areal extent of the total kelp canopy occupied by each of these individual species is dynamic from year to year and is thought to be influenced by a complex combination of physical, chemical, and biological factors. These fluctuations can have dramatic effects on the abundance and diversity of associated marine species.

The objectives of this resource inventory, as initiated in 1989, were threefold:

1) the establishment and maintenance of an annual, state-wide, coastal kelp resource mapping and monitoring program that would accurately reflect the seasonal maximum resource areal extent, by species;

2) the utilization of methodology that would allow not only a systematic, accurate analysis of multi-year data from current and future inventories, but would also allow meaningful comparisons with historic surveys as well;

3) the tabulation and presentation of kelp resource areal extent data at three levels, to serve: a/ field researchers conducting small-scale investigations within individual kelp forests; b/ administrative resource managers considering long-term trends over large areas; and c/ agency computer GIS professionals utilizing kelp canopy data as another data layer in a larger environmental resource model.

Appendix 7

Literature Cited

Bonnell, M.L., C.E. Bowlby, and G.A. Green. 1992. Pinniped distribution and abundance off Oregon and Washington, 1989-1990. Chapter 2 *In* J.J. Brueggeman (ed.), Oregon and Washington Marine Mammal and Seabird Surveys. Final Report prepared by Ebasco Environmental and Ecological Consulting, Inc. for the Minerals Management Service, Pacific OCS Region, Los Angeles, CA. OCS Study MMS 91-0093.

Briggs, K.T., D.H. Varoujean, W.W. Williams, R. G. Ford, M.L. Bonnell, and J.C. Casey. 1992. Seabirds of the Oregon and Washington OCS, 1989-1990. Chapter 3 *In* J.J. Brueggeman (ed.), Oregon and Washington Marine Mammal and Seabird Surveys. Final Report prepared by Ebasco Environmental and Ecological Consulting, Inc. for the Minerals Management Service, Pacific OCS Region, Los Angeles, CA. OCS Study MMS 91-0093.

Brown, C.L. 1977. Settlement and subsistence: A review of two sites on the southern Washington coast. Paper presented at the 30th Annual Northwest Anthropological Conference, Victoria, British Columbia.

Carney, D. and R.G. Kvitek. 1990. Shallow Subtidal Survey of the Washington Outer Coast and Olympic National Park to Determine the Distribution, Fate, and Effects of Spilled Bunker C Fuel Oil. Minerals Management Service and Battelle Marine Science Lab. OCS Study MMS 90-0073. 34 pp.

Clark, R.C., B.G. Patten and E.E. DeNike. 1978. .Observations of a cold-water intertidal community after 5 years of a low level persistent oil spill from the *General M.C. Meiggs. J. Fish. Res. Bd. Canada* 35: 754-765.

Daugherty, Richard D. 1948. Survey of the Washington Coast from Cape Flattery to Cape Disappointment. Manuscript, University of Washington Museum, Seattle, WA.

Dethier, M.N. 1988. A Survey of Intertidal Communities of the Pacific Coastal Area of Olympic National Park, Washington. U.S. Department of Interior, National Park Service.

Dethier, M.N. 1990. A Marine and Estuarine Classification System for Washington State. Natural Heritage Program, Washington Department of Natural Resources, Olympia, WA. 56 pp.

Dethier, M.N. 1991. The Effects of an Oil Spill and Freeze Event on Intertidal Community Structure in Washington. Minerals Management Service, Pacific OCS Region, Los Angeles, CA. OCS Study MMS 91-0002. 50 pp.

Dethier, M.N., D.O. Duggins, and T.F. Mumford. 1989. Harvesting of non-traditional marine resources in Washington State: trends and concerns. *Northwest Environmental Journal* 5: 71-87.

Duncan, M. A. 1981. Archaeological Investigations at La Push, Clallam County, Washington. Unpublished manuscript, Office of Public Archaeology, University of Washington, Seattle, WA.

Friedman, E. 1976. An Archaeological Survey of Makah Territory, Washington State. Washington Archaeological Research Center, Washington State University, Pullman, WA.

Gearhart, R.L. II, C.L. Bond, and S.D. Hoyt (eds.). 1990. California, Oregon, and Washington Archaeological Resource Study. Minerals Management Service, Pacific OCS Region, Los Angeles, CA. OCS Study MMS 90-01087.

Gleeson, P.F. 1980. Ozette Archaeological Project. Interim final report, Project Report 97, Washington Archaeological Research Center, Washington State University, Pullman, WA.

Green, G.A., J.J. Brueggeman, R.A. Grotefendt, C.E. Bowlby, M.L. Bonnell, and K.C. Balcomb III. 1992. Cetacean distribution and abundance off Oregon and Washington, 1989-1990. Chapter 1 *In* J.J. Brueggeman (ed.), Oregon and Washington Marine Mammal and Seabird Surveys. Final Report prepared by Ebasco Environmental and Ecological Consulting, Inc. for Minerals Management Service, Pacific OCS Region, Los Angeles, CA. OCS Study MMS 91-0093.

Guinn, S.J. 1962. White Rock Village Archaeological Site: A Preliminary Report of Investigations. Reports of Investigation 16, Laboratory of Anthropology, Washington State University, Pullman, WA.

Kidd, R. S. 1967. The Martin Site, southwestern Washington. *Tebiwa* 10(2).

Kinnetic Laboratories, Inc. 1992. Study of Recovery from an Oil Spill on the Rocky Intertidal Coast of Washington. Minerals Management Service, Pacific OCS Region, Los Angeles, CA. OCS Study MMS 92-0072.

Kvitek, R.G., P. Iampietro, and C.E. Bowlby. in prep. Sea otters and benthic prey communities in Washington State: A direct test of the sea otter as keystone predator hypothesis.

Kvitek, R. G., D.Shull, D. Canestro, E.C. Bowlby, and B.L. Troutman. 1989. Sea otters and benthic prey communities in Washington State. *Marine Mammal Science* 5: 266-280.

Landry, M.R. and B.M. Hickey (eds.). 1989. Coastal Oceanography of Washington and Oregon. Elsevier, Amsterdam. 607 pp.

Lie, U. and J.C. Kelley. 1970. Benthic infauna communities off the coast of Washington and in Puget Sound: identification and distribution of the communities. *J. Fish. Res. Bd. Canada* 27: 621-651.

Lie, U. and D.S. Kisker. 1970. Species composition and structure of benthic infauna communities off the coast of Washington. J. *Fish. Res. Bd. Canada* 27: 2273-2285.

McKay, P.J. 1990. Olympic Coast Gravel Barriers: Evolution, Morphology, and Process. M.S. thesis, Western Washington University, Bellingham, WA. 19 pp.

McKay, P.J. and T.A. Terich. 1992. Gravel barrier morphology: Olympic National Park, Washington State, USA. *Journal of Coastal Research* 8: 813-829.

Minor, R. 1983. Aboriginal Settlement and Subsistence at the Mouth of the Columbia River. Ph.D. dissertation, University of Oregon, Eugene, OR.

Newman, T.S. 1959. Toleak Point: An Archaeological Site on the North Central Washington Coast. Reports of Investigation 4, Laboratory of Anthropology, Washington State University, Pullman, WA.

National Oceanic and Atmospheric Administration (NOAA). 1993. Olympic Coast National Marine Sanctuary. Final Environmental Impact Statement/Management Plan. Vol. I, Sec. III: Research. U.S. Department of Commerce, Washington, D.C.

Office of Archaeology and Historic Preservation. n.d. Radiocarbon Dates from Archaeological Sites in Washington. Washington State Department of Trade and Economic Development, Office of Archaeology and Historic Preservation, Olympia, WA.

Olympic Natural Resources Center (ONRC). 1994. Research and education for managing the coastal resources of the Olympic Peninsula: Summary of a Conference, Aberdeen, WA, November 16-17, 1993. Olympic Natural Resources Center, Forks, WA.

Paine, R.T. 1980. Food webs: linkage, interactions, strength, and community infrastructure. *J. Animal Ecology* 49: 667-685.

Paine, R.T. 1986. Benthic community-water column coupling during the 1982-1983 El Niño; are community changes at high latitudes attributable to cause or coincidence? *Limnol. Oceanogr*. 31: 351-360.

Paine, R.T. and S.A. Levin. 1981. Intertidal landscapes: disturbance and the dynamics of pattern. *Ecological Monographs* 51: 145-178

Paine, R.T. and R.L. Vadas. 1969. The effects of grazing by sea urchins, *Strongylocentrotus spp.*, on benthic algal populations. *Limnol. Oceanogr*. 14: 710-719.

Reagan, A.B. 1917. Archaeological notes on western Washington and adjacent British Columbia. *Proc. Calif. Acad. Sci.* 4th Ser. 7(1): 1-31.

Rigg, G.B. 1912a. Ecological and economic notes on Puget Sound kelps. pp. 179-193 *In*: Fertilizer Resources on the United States. U.S. Senate Doc. 190.

Rigg, G.B. 1912b. Notes on the ecology and economic importance of *Nereocystis luetkeana*. *Puget Sound Biol. Sta. Publ.* 1: 83-92.

Rigg, G.B. 1915a. Seasonal development of bladder kelp. *Puget Sound Mar. Sta. Publ*. 1: 309-318.

Rigg, G.B. 1915b. The kelp beds of Puget Sound. U.S. Department of Agriculture Report 100: 50-59.

Rigg, G.B. 1925. Some physiology of the sieve tubes of *Nereocystis*. *Puget Sound Biol. Sta. Publ*. 3: 311-29.

Rigg, G.B. and R.C. Miller. 1949. Intertidal plants and animal zonation in the vicinity of Neah Bay, Washington. *Proc. Calif. Acad. Sci*. 4th Ser. 26: 32.

Roll, T. 1974. The Archaeology of Minard: A Case Study of a Late Prehistoric Northwest Coast Procurement System. Ph.D. dissertation, Washington State University, Pullman, WA.

Schwartz, M.L. and J. Mahala. 1984. Jefferson County, Washington, Net Shore Drift. Unpubl. report by Coastal Consultants for Washington Department of Ecology, Olympia, WA.

Schwartz, M.L. and J. Mahala. 1985. Clallam County – Juan de Fuca, Net Shore Drift. Unpubl. report by Coastal Consultants for Washington Department of Ecology, Olympia, WA.

Schwartz, M.L. and H. Bronson. 1984a. Pacific County, Washington, Net Shore Drift. Unpubl. report by Coastal Consultants for Washington Department of Ecology, Olympia, WA.

Schwartz, M.L. and H. Bronson. 1984b. Grays Harbor County, Washington, Net Shore Drift. Unpubl. report by Coastal Consultants for Washington Department of Ecology, Olympia, WA.

Schwartz, M.L. and S. Bubnick. 1984. Clallam County, Washington, Net Shore Drift. Unpubl. report by Coastal Consultants for Washington Department of Ecology, Olympia, WA.

Shaw, R.D. 1977. Report of Excavations: The Martin site (45Pc7), 1974. Occasional Paper 5, Washington Archaeological Society, Seattle, WA.

Simenstad, C.A., R.M. Thom, K.A. Kuzis, J.R. Cordell, and D.K. Shreffler. 1988. Nearshore Community Studies of Neah Bay, Washington. Final Contract Report to USCoE, Seattle District Environmental Resources Section, Seattle, WA.

Speich, S.M. and T.R. Wahl. 1989. Catalog of Washington Seabird Colonies. U.S. Fish and Wildlife Service Biological Report 88(6). 510 pp.

Stallard, B. and C. Denman. 1956. An Archaeological Site Survey on the Coast of Washington. Manuscript, Department of Anthropology, University of Washington, Seattle, WA.

Strand, J.A., V.I. Cullinan, E.A. Crecelius, T.J. Fortman, R.J. Citterman, and M.L. Fleischmann. 1992. Fate of bunker C fuel oil in Washington coastal habitats following the December, 1988 *Nestucca* oil spill. *Northwest Science* 66: 1-14.

Terich, T.A. and P. McKay. 1988. Olympic National Park Coastal Inventory and Monitoring. U.S. Dept. of the Interior, National Park Service.

U.S. Army Corps of Engineers. 1986. Quillayute River Navigation Project Long-Range Operations and Maintenance Final Environmental Impact Statement. Seattle District Environmental Resources Section, Seattle, WA.

Van Wagenen, R.F. 1996. Washington Coastal Kelp Resources – Port Townsend to the Columbia River. Final report by Ecoscan Resource Data to Olympic Coast National Marine Sanctuary.

Wessen, G. 1982. Shell Middens as Cultural Deposits. Ph.D. dissertation, Washington State University, Pullman, WA.

Wessen, G. 1983. Prehistoric Places on the Ocean Coast of Washington. *In* R.E. Greengo (ed.), Prehistoric Places on the Southern Northwest Coast. University of Washington Press, Seattle, WA.

Wessen, G. 1989. Historic Cultural Resources of the Coastal Strip of the Olympic National Park, Washington. Unpubl. manuscript, Wessen and Assoc.

Wilson, U.W. 1991. Responses of three seabird species to El Niño events and other warm episodes on the Washington coat, 1979-1990. *The Condor* 93: 853-858.

Woodbury, M.M. and M.N. Dethier. 1991. A Preliminary Survey of Rocky and Cobbly Intertidal Communities in Olympic National Park following the *Tenyo Maru* oil spill. Unpublished report, Olympic National Park, Port Angeles, WA. 14 pp.

General Background References for the Olympic Coast Marine Research Workshop

Armstrong, J. 1994. Marine monitoring programs in the border areas of Washington and British Columbia. U.S. Environmental Protection Agency, Region 10, Seattle, WA.

Armstrong, J. and A. Copping (eds.). 1990. Status and Management of Puget Sound's Biological Resources. Proceedings of the Forum on Puget Sound's Biological Resources – Status and Management, Seattle, WA, September 11-12, 1989. Puget Sound Water Quality Authority, Olympia, WA.

Bernston, G.M. 1988. Direct and indirect human impact on the sabellid polychaete, *Eudistylia vancouveri*. Unpublished report, Olympic National Park, Port Angeles, WA.

Bio/Tech Communications. 1988. Conference/Workshop on Recommendations for Studies in Washington and Oregon Relative to Offshore Oil and Gas Development, May 1988. Prepared for the U.S. Dept. Interior, Minerals Management Service, Pacific OCS Region, Los Angeles, CA. OCS Study MMS-88-0090. 213 pp.

British Columbia/Washington Marine Science Panel. 1994. The Shared Marine Waters of British Columbia and Washington. Report to the British Columbia/Washington Environmental Cooperation Council. 119 pp.

Cogan, Sharpe, & Cogan. 1986. OCS Policy Study. Report to Washington Department of Ecology, Olympia, WA.

Copping, A.E. and B.C. Bryant. 1993. Pacific Northwest Regional Marine Research Program. Vol. 1, Research Plan 1992-1996. Office of Marine Environmental and Resource Programs, University of Washington, Seattle, WA.

Dayton, P.K. 1985. Ecology of Kelp Communities. Annual Reviews Inc., Palo Alto, Calif.

Eng, M. 1994. Partnerships and Cooperation on the Olympic Peninsula: A Summary of Natural Resource Programs Relating to the Olympic Peninsula and an Analysis of How to Promote Cooperative Management of the Olympic Coast National Marine Sanctuary. Washington Sea Grant Program, Seattle, WA.

Green, G.A., J.J. Brueggeman, R.A. Grotefendt, and C.E. Bowlby. 1995. Offshore distances of gray whales migrating along the Oregon and Washington coasts, 1990. *Northwest Science* 69: 223-227.

Green, G.A., R.A. Grotefendt, M.A. Smultea, C.E. Bowlby, and R.A. Rowlett. 1993. Delphinid aerial surveys in Oregon and Washington offshore waters. Final Report to the National Marine Mammal Laboratory, National Marine Fisheries Service, Seattle, WA.

Horner, R.A. and J.R. Postel. 1993. Toxic diatoms in western Washington waters. *Hydrobiologia* 269/270: 197-215.

Huelsback, D.R. 1983. Mammals and Fish in the Subsistence Economy of Ozette. Ph.D. dissertation, Washington State University, Pullman, WA.

Kendrick, G.A. and B.B. Moorhead. 1986. Monitoring Recreational Impact on Intertidal Biotic Communities, Pacific Coastal Area, Olympic National Park. Unpubl. Progress Report, Olympic National Park, Port Angeles, WA. 38 pp.

National Research Council. 1990. Managing Troubled Waters: the Role of Marine Environmental Monitoring. National Academy Press, Washington, D.C. 125 pp.

O'Connor, T.P. and B. Beliaeff. 1995. Recent trends in coastal environmental quality: results from the NOAA Mussel Watch Project 1986 to 1993. National Status and Trends Program. U.S. Department of Commerce, Washington, D.C.

Puget Sound Water Quality Authority. 1995a. Puget Sound Research '95. Proceedings of the Puget Sound Research '95: A conference about research on Puget Sound and the Strait of Georgia. Puget Sound Water Quality Authority, Olympia, WA. 137 pp.

Puget Sound Water Quality Authority. 1995b. 1994 Puget Sound Update: Fifth Annual Report of the Puget Sound Ambient Monitoring Program. Puget Sound Water Quality Authority, Olympia, WA.

Puget Sound Water Quality Authority. 1995c. Puget Sound Ambient Monitoring Program Review: Task Briefing Papers, Review Workshop June 6, 1995. Puget Sound Water Quality Authority, Olympia, WA.

Puget Sound Water Quality Authority. 1995d. Puget Sound Ambient Monitoring Program Review: Issue and Recommendation Papers. Review Workshop September 26-28, 1995. Puget Sound Water Quality Authority, Olympia, WA.

Strickland, R. and D.J. Chasan. 1989. Coastal Washington: A Synthesis of Information. Washington Sea Grant Program, Seattle, WA.

Taylor, F.J.R. and R.A. Horner. 1994. Red Tides and other problems with harmful algal blooms in Pacific Northwest coastal waters. *In* Wilson, R.C.H., R.J. Beamish, F. Aitkens, and J. Bell (eds.). 1994. Review of the Marine Environment and Biota of Strait of Georgia, Puget Sound and Juan de Fuca Strait. Proceedings of the B.C./Washington Symposium on the Marine Environment, Vancouver, B.C., January 13-14, 1994. Canadian Technical Report of Fisheries and Aquatic Sciences No. 1948.

Technical Subcommittee of the Pacific Northwest OCS Task Force. 1990. Environmental Studies for Washington and Oregon Relative to Lease Sale Planning Area 132. Technical

Subcommittee recommendation to the Pacific Northwest OCS Task Force. U.S. Department of the Interior, Minerals Management Service, Pacific OCS Region, Los Angeles, CA.

Wilson, R.C.H., R.J. Beamish, F. Aitkens, and J. Bell (eds.). 1994. Review of the Marine Environment and Biota of Strait of Georgia, Puget Sound and Juan de Fuca Strait. Proceedings of the B.C./Washington Symposium on the Marine Environment, Vancouver, B.C., January 13-14, 1994. Canadian Technical Report of Fisheries and Aquatic Sciences No. 1948.

Appendix 8

List of Acronyms

AEC	Atomic Energy Commission
ACE	U.S. Army Corps of Engineers
AOP	Annual Operating Plan
ASP	Amnesic Shellfish Poisoning
AVHRR	Advanced Very High Resolution Radiometer
CTD	Conductivity, Temperature, Depth
DEIS	Draft Environmental Impact Statement
DOE	U.S. Department of Energy
DSP	Diarrhetic Shellfish Poisoning
ENSO	El Niño Southern Oscillation
EPA	Environmental Protection Act
ERDA	Energy Research and Development Administration
ESA	Endangered Species Act
FEIS	Final Environmental Impact Statement
GIS	Geographic Information System
IOC	International Oceanographic Commission
IOS	Intstitute of Ocean Sciences, Sydney, B.C.
MMPA	Marine Mammal Protection Act
NDBC	National Data Buoy Center, NOAA
NMFS	National Marine Fisheries Service, NOAA
NMML	National Marine Mammal Laboratory, NOAA
NOAA	National Oceanic and Atmospheric Administration
NODC	National Oceanographic Data Commission, NOAA
NPDES	National Pollution Discharge Elimination System
NPS	National Park Service
NWIFC	Northwest Indian Fisheries Commission
OCNMS	Olympic Coast National Marine Sanctuary, NOAA
ONP	Olympic National Park
ONRC	Olympic Natural Resources Center, UW
OSU	Oregon State University
PMEL	Pacific Marine Environmental Lab, NOAA
PSG	Pacific Seabird Group
PSP	Paralytic Shellfish Poisoning
RDA	Resource Damage Assessment
RFP	Request for Proposals
SAC	Sanctuary Advisory Committee
SRD	Sanctuaries and Reserves Division, NOAA
SRP	Sanctuary Research Plan
USCG	U.S. Coast Guard
UBC	University of British Columbia

USFWS	U.S. Fish & Wildlife Service
UVIC	University of Victoria
UW	University of Washington
WDE	Washington Department of Ecology
WDFW	Washington Department of Fish & Wildlife
WDH	Washington Department of Health
WDNR	Washington Department of Natural Resources